Towards zero waste: The search for effective waste management policy to support the transition to a circular economy.

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Towards zero waste: The search for effective waste management policy to support the transition to a circular economy.

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Abstract

The circular economy has been widely adopted to address the issues of unsustainable production and consumption associated with the linear economy. However, implementation has been limited by several factors. With many barriers linked to poor waste management, effective waste policy is vital in the transition to the circular economy. By prioritising landfill diversion and promoting the waste hierarchy, European Union (EU) policy has driven substantial regional advances in waste management. The EU has recently identified the transition to the circular economy as a key policy objective. However, critics highlight a continued emphasis on end-of-pipe strategies, which are often low on the waste hierarchy (e.g. targets focused on recycling and landfill diversion with no limits on incineration). Thus, to meet current targets, member states have increasingly invested in mechanical biological treatment and incineration; changing the nature of residual wastes and increasing the risk of lock-in. This thesis explores the adoption of EU policy by member states and considers these associated risks. While the EU sets overarching targets, members can choose to adopt the minimum requirements (copy-out) or seek to go beyond them (gold-plated). A document analysis of UK waste strategy found clear alignment with EU policy across the four home nations, albeit with different levels of implementation. Adopting a gold-plated approach, Scotland introduced a carbon metric and sought to limit incineration, while Wales promoted stakeholder inclusion. In contrast, England and Northern Ireland adopted the copy-out approach. Regarding the management of residuals (fines and incinerator bottom ash), current policy instruments may have unintended consequences. With regard to the use of landfill taxes to promote diversion, a stakeholder survey found that secondary legislation introduced to classify fines may limit material recovery and discourage investment, thereby creating a perverse incentive for landfill disposal. Additionally, analysis of EU waste management data found a growing dependence on incineration to achieve near-term targets that may disincentivise material recovery and increase risks of lock-in. Overall, to address barriers to the circular economy, and to realise future targets, future-proofing of waste policy is recommended. Presented as a first step to achieve this, the Circular Economy Readiness concept is introduced. Drawing parallels with readiness in the energy sector, a workshop identified the need to develop societal, as well as technological readiness, alongside mechanisms to address specific waste management issues.

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Contents

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Abbreviations

3TG minerals – Tin, Tantalum, Tungsten and Gold: resources known as conflict minerals.

AAC – Autoclaved Aerated Concrete

Basel Convention – Basel Convention on the Control of Transboundary Movement of Hazardous Wastes and their Disposal

BMW – Biological Municipal Waste

Brexit – Withdrawal of the United Kingdom from the European Union

CCR – Carbon Capture Readiness

CCS – Carbon Capture and Storage

C&D – Construction and Demolition

CEP – Circular Economy Package

CEWEP – Confederation of European Waste-to-Energy Plants

CRM – Critical Raw Materials

CIWM - Chartered Institute for Waste Management

CO^2 – Carbon dioxide

COP21 – 21^{st} Conference of Parties

CRM – Critical Raw Materials

EC – European Commission

EFTA – European Free Trade Association

EoW – End of Waste

EPR – Extended Producer Responsibility

ERA – Ecosystem Readiness Assessment

EU – European Union

EWC – European Waste Catalogue

EWSR – European Waste Shipment Regulations

GCM – Global Circularity Metric

GD/NGPB - Governmental Department / Non-Governmental Public Body

GHG – Greenhouse Gas

HMRC – Her Majesty's Revenue and Customs

ICP-MS – Inductively Coupled Plasma – Mass Spectrometry

IPCC – Intergovernmental Panel on Climate Change

IRLs – Integrated Readiness Levels

ISO – International Standards Organisation

LD – Landfill Directive (1999/31/EC)

LOI – Loss on Ignition

MBT – Mechanical Biological Treatment

MFA – Material Flow Analysis

MRF – Material Recovery Facility

MSI – Material Security Index

MSW – Municipal Solid Waste

MSW-IBA – Incineration Bottom Ash from the incineration of MSW

N/A - Not Applicable

NASA – National Aeronautics and Space Administration

NI – Northern Ireland

NS-SEC – National Statistics Socio-Economic Classification

PPWD – Packaging and Packaging Waste Directive (1994/62/EC)

QFO – Landfill Tax (Qualifying Fines) Order 2015

QF – Qualifying Fines

QMO – Landfill Tax (Qualifying Materials) Order

Quan – Quantitative research methodologies

Qual – Qualitative research methodologies

RED II – EU Renewable Energy Directive

REE – Rare Earth Elements

RDI – Recycling Desirability Index

ROI – Return on Investment

RQ – Research Question

SCP/SPC - Sustainable Production and Consumption

SRF – Substance Flow Analysis

SRLs – Systems Readiness Levels

SUM 2018 - Fourth Symposium on Urban Mining and Circular Economy

TRLs – Technology Readiness Levels

UK – United Kingdom

UK LFT – United Kingdom Landfill Tax

UN – United Nations

WAG – Welsh Assembly Government

WFD – updated Waste Framework Directive (2008/98/EC)

WHI – Waste Hierarchy Index

WMS – Waste Management Strategy

WPP – Waste Prevention Plan

X^2 – nonparametric Pearson’s Chi-Square

XRF – X-Ray Fluorescence

CHAPTER 1: Introduction

Increasing levels of unsustainable consumption are the result of the continued dominance of the linear economy and are exacerbated by increasing global population and growing personal affluence (Niazi et al., 2015). While the linear economic model has improved the quality of life for the current generation, unfavourable consequences, such as environmental degradation and grand societal challenges (e.g. resource depletion, climate change, and geopolitical tensions) are becoming evident (Clark, 2007; Moreno et al., 2016). In a linear economy, where the continuous throughput of materials is required, there is a constant demand for resources, and the generation of pollution and emissions are expected. This coupling of economic growth and resource use has been identified as a key limitation of the linear economy.

To address the limitations and consequences of the linear economy, the transition to the circular economy has been recommended. As an approach that decouples economic growth from resource use, the circular economy simultaneously meets the sustainable development objectives of; economic growth, social progress and environmental protection. The circular economy promotes resource efficiency, optimises production systems, maintains resource utility, and recovers any remaining value through progressive waste management strategies (Smol et al., 2015).

However, to be successful, implementation of the circular economy needs to promote transformational change, must acknowledge and engage a range of stakeholders, and needs to be sustainable (economically, operationally, technologically, environmentally and politically) both at a local and global level. This requires international recognition, agreement and adoption, where a common vision for the circular economy is developed and implemented.

1.1 The research problem

While the need to transition to the circular economy has gained international recognition, a universal definition of a circular economy, and an understanding of how to successfully transition, is still subject to debate and interpretation (Kirchherr et al., 2017). Thus, adoption of the circular economy is currently restricted by a poor level of agreement amongst international stakeholders. Furthermore, barriers within existing socio-technical systems, some of which can be attributed to the poor quantification and management of materials and wastes, have limited any attempts of implementation. It has been suggested that some of these barriers could be addressed through effective waste policy (Ritzén and Ölundh Sandström, 2017; Salemdeeb et al., 2016). However, for waste management policy to be effective, and thereby contribute to the transition to the circular economy, it must overcome existing limitations and barriers.

This research explores the potential contribution of waste management policy to the transition to, and implementation of, the circular economy. Importantly, this research identifies limitations in the implementation of existing waste and resource management policy, as well as examples of good practice. These limitations it is argued will present barriers in the transition to the circular economy, and thus mechanisms to avoid or overcome these barriers should be developed.

The intended outcome of this research is to identify existing barriers within waste management policy, which could impede the transition to the circular economy, and to explore potential solutions and concepts that could inform future waste policy. This research is therefore exploratory in nature, and framed by the following aim;

To identify and address potential limitations within EU and UK waste policy that may be acting as barriers in the transition to the circular economy.

1.2 Thesis outline

The overall structure of this thesis is presented in Figure 1, and Chapters 2 – 8 are summarised below.

Chapter 2 provides context to the thesis by reviewing literature on the following; the linear economy and unsustainable consumption, alternatives to the linear economy, the circular economy (conceptual, adoption and implementation), the role of waste and resource management in the transition to the circular economy and finally, existing limitations within waste and resource management policy. The overall aim of this thesis, and associated research questions are then presented.

Chapter 3 presents the research methodology, which first discusses the role of philosophical paradigms in the choice of research design, and which strategies of enquiry can be used. Adopting a pragmatist viewpoint, this study employs a mixed methods research design, where multiple strategies across the Quantitative-Qualitative continuum are utilised.

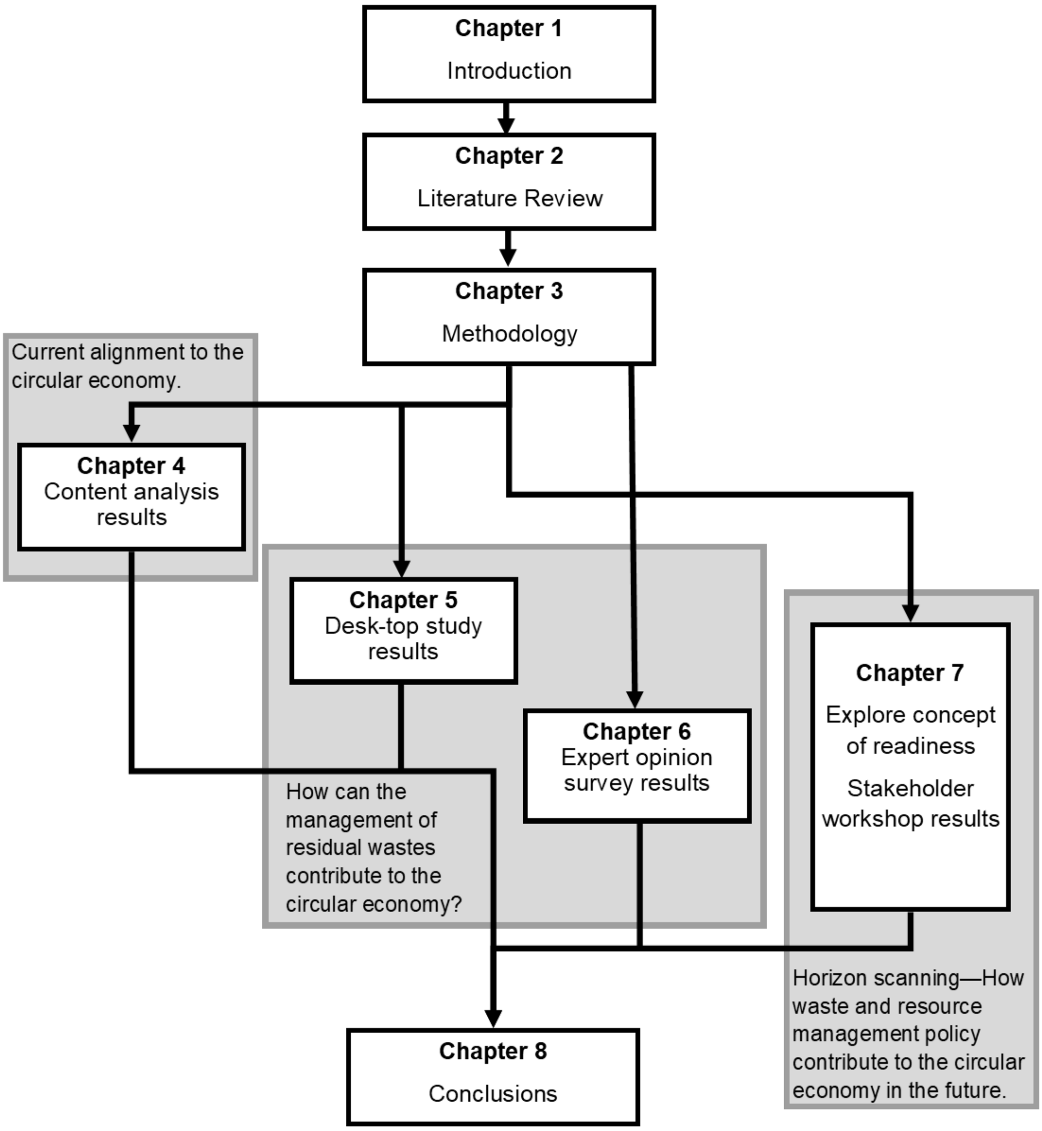


Figure 1: Thesis outline

Chapter 4 presents the results of a content analysis, where a Framework (developed in Chapters 2 and 3) was utilised to compare the waste strategies (plus two associated waste prevention plans) of the four devolved nations of the UK (England, Scotland, Wales and Northern Ireland).

Chapter 5 presents the results of a desk-top study, which focuses on resource efficiency, the utilisation of residual materials, limitations of technological lock-in, and future-proofing. It explores the increasingly prominent role of incineration within EU waste and resource management, highlighting the potential risk of technological lock-in and the use of measures (namely End of Waste criteria) to increase resource efficiency with the utilisation of residual waste materials.

Chapter 6 presents the results of an expert opinion survey that focuses on the introduction of ineffective waste and resource management policy, which may hamper efforts to improve resource efficiency. It illustrates an example of where fragmented secondary legislation (introduced to address specific issues) creates a barrier to the aims of the primary legislation. Specifically, this chapter highlights amendments made to the UK Landfill Tax, namely the Landfill Tax (Qualifying Fines) Order 2015, which have dis-incentivised further landfill diversion.

Chapter 7 explores the concept of 'readiness' and its potential application to the waste and resource management sector in the transition to the circular economy. In addition, this chapter presents the outcomes of a stakeholder workshop, where the contribution of the waste and resource management sector to the transition to the circular economy, along with existing barriers and suggested solutions were identified.

Finally, **Chapter 8** draws on the findings of chapters 4 – 7 to present the primary conclusions and recommendations of this research, as well as contribution to knowledge, implications to theory, practice and policy, and potential future lines of enquiry.

1.3 Contribution to knowledge

This research is both novel and timely, particularly with the growing international recognition for the need of adopting a circular economy, and the recent introduction of the EU Circular Economy Package (CEP) (EC, 2015a). Furthermore, this research identifies the role of waste and resource management policy in aiding the transition to the circular economy.

The main contribution of this research is the conceptualisation of the circular economy, the contribution of waste management policy to the transition to the circular economy, and the identification of limitations within existing waste and resource management policy that may create barriers to the circular economy in the future. Specifically, this study acknowledges the progress made within waste and resource management over the past two decades. It explores the management of two residual wastes; Incineration Bottom Ash and Fines. Residual wastes are often acknowledged within the literature as an output of current waste management strategies; however, limited research has been completed on the management of such wastes, particularly in light of current and evolving policy. In addition, this research applies the concept of readiness to the waste and resource management sector in the context of supporting the transition to the circular economy.

Elements of this research have been presented at several conferences (for a list of conference participation, see Appendix 1: Thesis outputs). In addition, two articles have been published in peer-reviewed journals. The first, presents a content analysis that compared the waste strategy documents of the four devolved nations of the UK against a circular economy framework (Chapter 4). This article has been published in the peer-reviewed journal; Detritus (see Appendix 2: Fletcher and Dunk, 2018 for a copy of the full paper). The second evaluates the implementation of secondary legislation, namely the Landfill Tax (Qualifying Fines) Order 2015, and its impact on the waste industry and landfill diversion objectives through an expert opinion survey (Chapter 6). This article has been published in the peer-reviewed journal; Resources, Conservation and Recycling (see Appendix 3: Fletcher et al., 2018 for a copy of the full paper).

CHAPTER 2: Literature review

2.1 Chapter overview

This chapter first examines the linear economic model, and the issues associated with unsustainable consumption. Addressing the grand societal challenges caused by unsustainable consumption, the circular economy is then introduced as an alternative to linear economic model, where the concept will be defined and current levels of implementation and its application to socio-technical systems are discussed. One socio-technical system, waste and resource management, will be explored in terms of its role both within, and during the transition to the circular economy, where the effectiveness of current policy is reviewed. Finally, a summary of the literature review is presented where the aims and research questions of the study are introduced.

2.2 The world we currently live in…

Since the industrial revolution, the dominant economic paradigm: the linear economy, has stimulated growth worldwide. The dependence on this economic paradigm has promoted unsustainable consumption and generated a range of associated negative impacts. To provide a broader context, this section explores the drivers and consequences of the linear economy in more detail.

2.2.1 What is the linear economic model and how did it become dominant?

The basis of the linear economic model is the throughput of resources and materials through an economy (Figure 2). In the linear economic model, raw resources extracted from the earth, such as petroleum oil, inorganic minerals and metal ores, are processed and / or manufactured in materials or products, then sold for use by a consumer. Once the consumer believes the material or product to be redundant it is then discarded (Smol et al., 2015; Clark, 2007).

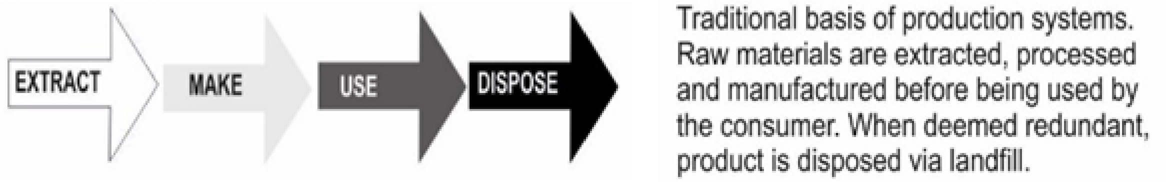


Figure 2: The linear economy (based on Smol et al., 2015; Clark, 2007)

Based on the neoclassical economic model, the linear economy fosters opportunities for producers and companies to maximise their profits, mainly through the supply and demand of goods and services (Kenton, 2018). Here, the basis of value is utility to humans, where the aim is to satisfy the needs and wants of the human population (Blauwhof, 2012; Kenton, 2018). To achieve this, resources have only commercial value, with no intrinsic value and the environment is assumed to be constant and stable (Hawken et al., 2013). Based on industrial capitalism, this mode of production and consumption promotes private ownership and financial profitability. It does not assign value to natural resources or human capital, i.e. social and cultural systems (Hawken et al., 2013). This conventional worldview believes that economic progress (i.e. growth in total output), maximises human well-being, and is fostered by a free-market system, where reinvested profits increase productivity, and competition expands markets (Hawken et al., 2013).

The linear economic model gained prominence after the Second World War, when governments encouraged the increased production and consumption of goods and services to achieve full employment (Victor and Jackson, 2015). In promoting economic growth, governments were also successful in raising tax revenues and stimulating better standards of living for their citizens. However, while some governments have reaped the rewards of the linear economic model, the distribution of benefits is not equal amongst nations (Victor and Jackson, 2015). Indeed, even within some nations, the distribution of benefits is not equal. Nonetheless, less-developed nations have recognised the use of economic growth to improve living standards, and thus look to emulate the development arch of developed nations (Cranston and Hammond, 2010).

2.2.2 The linear economic model sounds great, what is the catch?

While economic growth has been integral to the development arch of many nations, the association between economic growth and resource use, promoted by the linear economy model, is becoming an increasingly pertinent issue.

Economic growth, within the current paradigm, requires the ever-increasing consumption of natural resources, and the utilisation of natural resources to absorb wastes, particularly carbon emissions. The increased reliance on natural assets to provide both source and sink resources has led to increased resource depletion and the reduction in the capacity of sinks to deal with the wastes created, both of which will restrict the utilisation of natural assets in the future (Mawle, 2010). Within the parameters of the linear economic model, which requires the continual throughput of resources from these assets, this model of consumption and production is unsustainable. In fact, the inherent characteristics of the linear economic model, as well as external drivers such as population growth and increasing affluence, are driving unsustainable consumption further.

While the linear economic model expects the generation of pollution, waste and emissions, market prices do not account for these impacts. Instead, the linear economic model classifies pollution, waste and emissions as negative externalities, or market failures. While such market failures are caused when allocated resources are not sufficient enough to generate the most efficient outcome, by not accounting for negative externalities, companies can offer products and services at a lower price, thus promoting further consumption (Atkinson and Tietenberg, 1991; Jaffe *et al*., 2005; Mankiw, 2011).

Rising population numbers, as well as growing affluence, has increased the consumption of goods and services globally (Niazi et al., 2015). Current estimations expect the human population to increase by more than 50% (from 2015 baseline) to 11.2 billion people by 2100 (UNESA, 2015; Bongaarts, 2016). Through technology, social organisation and culture, the human population has been able to defy density-dependant regulation mechanisms, which often limit the growth of other animal populations (Ghirlanda et al., 2010). Indeed, the expansion of the human population has often coincided with technological change, which has increased consumption and promoted economic growth. However, if populations expand too rapidly, as well as increased consumption, negative consequences can include economic stagnation and political unrest (Bongaarts, 2016). Of course, it is not only the number of people that drive unsustainable consumption but also the expected standard of living, i.e. expectations of choice, comfort, cleanliness and convenience (Fischer, 2012).

Developed nations are characterised by high levels of human development, particularly high standards of living and personal affluence, along with increasing levels of consumption. This disproportionate per capita consumption in (richer) developed nations is a key driver of unsustainable consumption (Fischer, 2012). Given that a key development objective of less-developed nations (developing and / or emerging economies) is to emulate the human development and economic growth levels of developed nations, greater levels of unsustainable consumption are expected in the future (Cranston and Hammond, 2010). Indeed, a link between development and resource use has been acknowledged, with Dias et al. (2006) and Niu et al. (2013) identifying positive relationships between human development and consumption. Niu et al. (2013) notes a bidirectional link where increased energy consumption (particularly that of electricity) promotes human development; conversely increased human development expands the social demand for energy. Similarly, in the consumption of other resources, bidirectional relationships are also present. Dias et al (2006) recognises that the consumption of non-essential items promotes an increased standard of living and a higher level of affluence (a key component of human development). Conversely, consumers with a higher level of affluence are more likely to consume non-essential items.

To summarise, with a growing global population the increasing number of individuals will drive further unsustainable consumption to meet the **needs** of those individuals. Furthermore, with growing levels of affluence, not only will there be a greater proportion of the global population that are more affluent, but also the absolute number within this proportion will increase, driving further unsustainable consumption to meet the **wants** of these individuals.

While increased levels of consumption have improved the quality of life for the current generation, unfavourable consequences such as environmental degradation and grand societal challenges (e.g. resource depletion, climate change, and geopolitical tension) are becoming evident (Clark, 2007; Moreno et al., 2016).

With respect to resource depletion, there is a continuing and growing decline in the availability of many non-renewable resources expected in the future. The concept of ‘limits to growth’, developed by the Club of Rome, modelled unconstrained economic and population growth against finite resource availability (Meadows et al., 1972). Based on the Neo-Malthusian view, ‘limits to growth’ argues that the arithmetic availability, or carrying capacity, of any resource used can place a restriction on the exponential growth of a population. Meadows et al. (1972) concluded that if economic and population growth continued unabated, i.e. under a business as usual scenario, then limits would be evident by 2072 with an expected sudden and uncontrollable decline in population and industrial capacity. More recently, the think-tank, Plan C (now merged within the Flanders’ Materials

Programme) estimated the depletion of twelve critical resources to non-economic levels over the next five decades (Plan C, 2014). Here, non-economic levels are defined as the point where costs of extracting resources, due to inaccessibility or poor availability, exceeds the market price of those resources, thereby making extraction uneconomical. As illustrated in Figure 3, the predicted lifespan of non-renewable resources such as fossil fuels (coal, oil, gas, etc.), precious metals (zinc, silver, gold etc.) and other critical elements (antimony, lead, etc.) are likely to end during this century. Based on current rates of economic growth, these estimates assume continuation of the linear 'take-make-dispose' economic model (Plan C, 2014). Even if a static rate of economic growth was achieved, it is predicted that the lifespan of the majority of non-renewable resources would not extend beyond the current century (Figure 3).

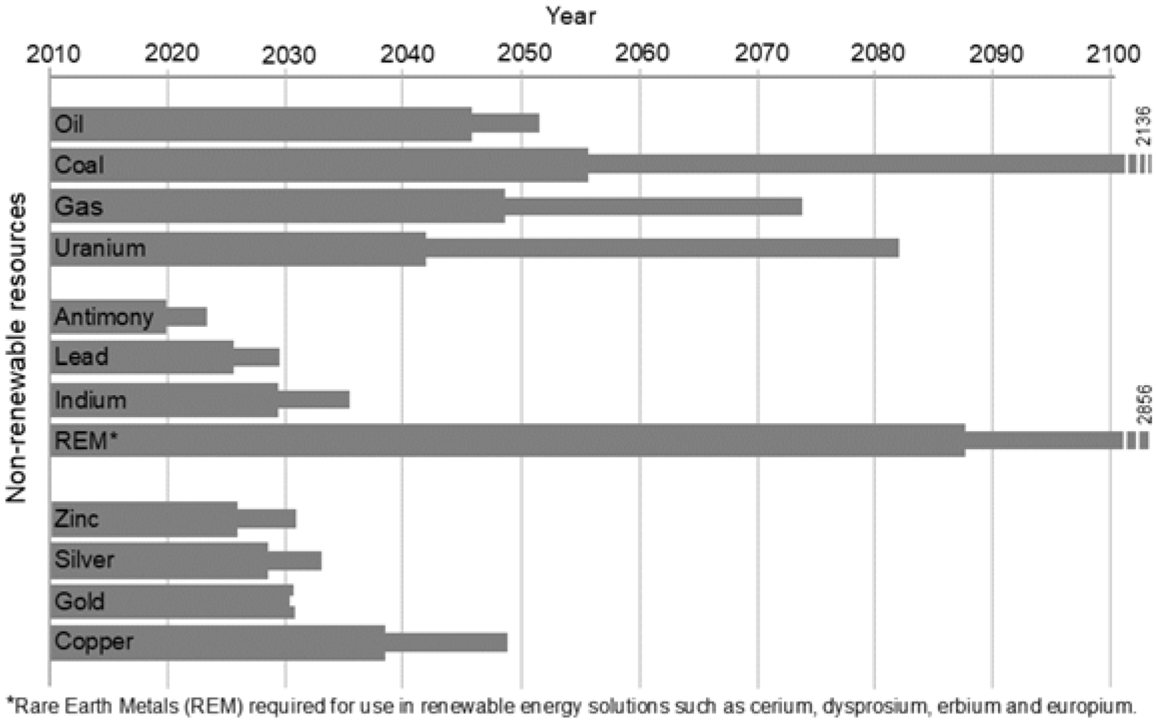


Figure 3: Predicted lifespan of virgin stocks for twelve critical non-renewable resources under current rates of growth (thick bars) and under static growth (thin bars) (Plan C, 2014).

Characterisation of economic growth to date, with the increased consumption of resources and greater requirement for energy, has been heavily reliant on the extraction, combustion and utilisation of fossil fuels. In addition, the growing human population has required more space, which has resulted in land use change, reduced land availability, degradation of agricultural land, and deteriorating biodiversity. Collectively this has contributed to climate change, primarily through increased emissions of greenhouse gases such as carbon dioxide (from the combustion of fossil fuels) and methane (from agriculture and waste). In addition, there is a reduced capacity of ecological systems to act as an emission sink (Mawle, 2010). Current estimates by the Intergovernmental Panel on Climate Change (IPCC), has seen climate change contribute to a 1°C rise in the temperature of the world's climate. Under current conditions, the IPCC has predicted this to rise a further 1.5°C by 2052, which would lead to long-term changes in climate systems such as sea level rise, ocean acidification and the loss of some ecosystems (IPCC, 2018).

Climate change has a further impact on water availability, where the former has a direct effect in the availability of the latter. This is caused by variations in the amount of rainfall deposited, and the amount of water evaporated due to increased temperatures (IPCC, 2018). In the current economic paradigm, the extraction and processing of raw materials use large volumes of water, which can conflict with food production, potable water and sanitation. Competition for water and other depleted resources can also lead to conflict and other geo-political tensions (Mawle, 2010).

Based on the continual throughput of materials, within the linear economic model there is a constant demand for raw resources. In addition to the environmental impacts of resource degradation, associated social issues can also arise from the procurement of, and thus competition for, resources. Local environmental issues, such as the shortage of fresh water and arable land, and the mounting volume of wastes and pollution generated, have had an adverse impact on human health and threatens foods security (Bongaarts, 2016). Furthermore, social infrastructure often fails to keep up with explosive population growth, leading to high unemployment, development of slums, and under-resourced public services, e.g. schools, health systems, sanitation and transport (Bongaarts, 2016). In the most extreme cases, the trade of resources, such as conflict minerals including Tin, Tantalum, Tungsten and Gold (also known as the 3TG minerals), is explicitly linked with financing conflicts and civil wars, for example within eastern Democratic Republic of Congo (Young, 2018). Like climate change, the issue of conflict minerals is not a local one. While extracted from areas where humanitarian conditions are severely poor, and can include high levels of child labour, sexual violence and civil unrest, the demand for 3TG minerals within a wide range of products, especially electronics, attracts an international market (Young, 2018). The disconnection between the supply of, and demand for, resources creates an opaque buyer-supplier relationship, often exacerbated by complex and dispersed supply chains (Kim and Davies, 2016). The consequence of which, limits sustainable supply chain management by masking the origin of raw resources used in the final consumer product, and limiting the ability to collect information across the supply chain (Kim and Davies, 2016).

2.2.3 So, how do we address these issues?

Environmental policies have attempted to address market failures through efforts to internalise externalities. Within Europe, environmental policies have been introduced to ensure the careful use of resources, minimise negative environmental impacts of production and consumption, and to protect biodiversity and natural habitats (Wysokińska, 2016). There are three main types of environmental policy instrument (Wurzel et al., 2013);

1. **suasive instruments**, the 'softest' policy instrument type, which rely on informational measures and voluntary agreements,
2. **market-based instruments**, which have been propagated over a long time on the grounds of cost-effectiveness and include taxes and tradable permits, and
3. **regulatory instruments**, also known as command-and-control regulation, which are the most authoritarian of the policy instruments and based on a (/or set of) prescriptive rule(s) backed by sanctions.

Evolution of policy instruments tend to follow one of four routes. The first route sees separate instruments introduced where they co-exist and complement one another. The second route allows two or more instruments to merge and thus, become a fusion instrument. The third route sees the introduction of instruments, which then competes against an existing instrument. Finally, the fourth route sees the introduction of one instrument supplant and replace another. Of the four types of evolution routes, environmental policy tends to be focus on route two, whereby new instruments are added to a policy field already populated with old instruments (Wurzel et al., 2013).

The effectiveness of environmental policy is often limited due to the trade-off between abatement and remediation, with markets regularly aligning with the cheapest option, often remediation, rather than the environmentally and / or socially optimum (Shmelev, 2012). In addition, current costs and future uncertainties regarding markets and policy frameworks have created a reluctance to invest in abatement technology that controls and reduces the release of discharges (Jaffe et al., 2005).

As well as dealing with the negative outputs of production and consumption, the introduction of mechanisms, such as eco-efficiency, also consider inputs. The implementation of eco-efficiency seeks to reduce environmental impacts while increasing the value of production (EMF, 2012; Jaffe et al., 2005). Within the current production and consumption mode, this would require production systems to use fewer resources, to improve product design and to realise the benefits of avoiding pollution control measures, such as the lower financial costs of waste management, energy use and material procurement (EMF, 2012; Jaffe et al., 2005). Within the current neoclassical model, efforts to internalise externalities and to introduce eco-efficiency mechanisms have been limited due to the continuing emphasis on quantitative economic growth, where trade-offs continue to benefit profit maximisation (EMF, 2012; Jaffe et al., 2005).

Clearly, the emphasis of the current economic model is unsustainable, particularly in combination with population growth and increased affluence. Therefore, to address the limitations and consequences of the linear economy, an economic model with a different fundamental structure and value system is required (Victor and Jackson, 2015). Over the last few decades, ‘ecological economics’, the ‘de-growth economic model’ and the ‘steady-state economic model’, amongst many others; have been put forward as suitable alternatives.

The ecological economic model is fundamentally different to the current economic model, as it; internalises all externalities, and advocates eco-effectiveness rather than eco-efficiency. While eco-efficiency maintains a linear model, seeking to use resources more efficiently to maximise profits, eco-effectiveness transforms products and materials, so that both ecological systems and future economic growth are supported (EMF, 2012). To do that, the ecological economic model mimics the cyclic nature of natural systems where discharges are utilised as resources in closed-loop systems. The ecological economic model emerged in response to increasing environmental issues, which the neoclassical economic model seems unable to solve (Shmelev, 2012). By placing the economy as a subsystem of the biosphere, ecological economics addresses the relationship between ecosystems and economic systems. It assumes that ecosystem changes are non-linear, and that matter and energy are in a continuous state of transformation (Shmelev, 2012).

To address the consequences of the linear economic model, consideration should be given to the decoupling of resource use from economic growth, and biophysical limits. To do this, qualitative growth is emphasised, where human well-being and ecological conditions rather than quantitative economic growth are prioritised (Kerschner, 2010). The de-growth model restricts the size of the economy and downscales levels of production and consumption. This model is of particular use when a system that has grown unabated within the conventional economic model, has surpassed biophysical limits. By restricting the economy, the de-growth model allows the system to return to, and function within, the limits placed (Kerschner, 2010). Once returned to, or already functioning within the biophysical limits, the de-growth economic model should be replaced by the steady-state economic model. This would ensure that economic outputs remain at a stable level and support ecological stability (Blauwhof, 2012).

While the development of these alternative economic models aimed to address the various issues of the linear economic model, many have remained theoretical with none adopted. To be successful, an alternative economic model needs to promote transformative change, which governments cannot achieve alone, and is economically, operationally, technologically, environmentally and politically sustainable. As an alternative, the circular economy takes elements from ecological economics, de-growth economics and steady-state economics and engages with governments, industry and consumers.

2.3 Turning things around with the Circular Economy

As illustrated by Figure 4, the circular economy re-circulates resources and materials throughout the production and consumption cycle. To do this, the optimisation of production systems promotes resource efficiency, maximises the value of a resource when in use and recovers any remaining value once discarded, thereby maintaining resource utility (Smol et al., 2015).

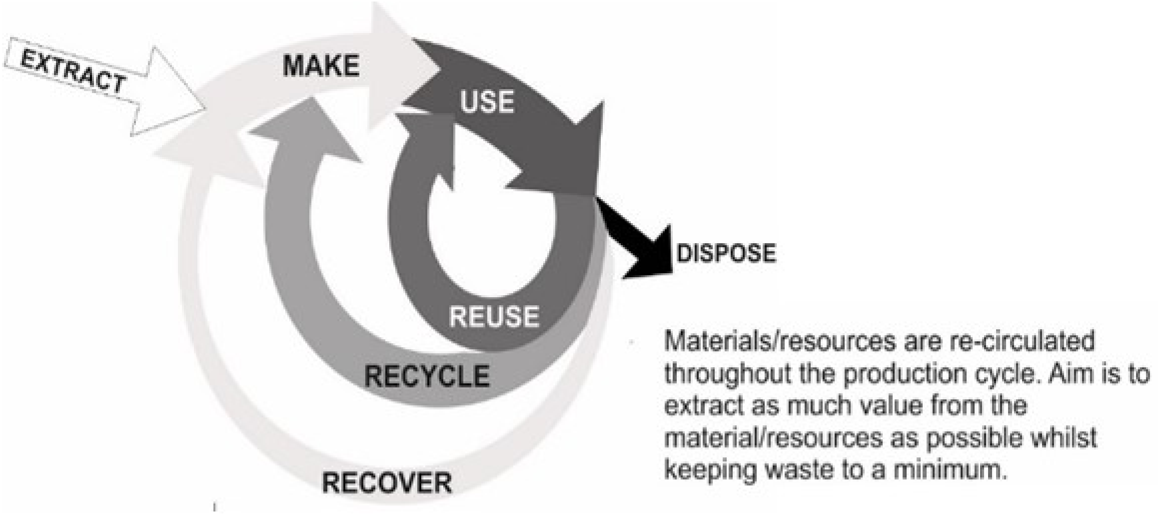


Figure 4: The concept of the circular economy (based on Smol et al., 2015; Clark, 2007).

At its core, the circular economy is a broad resource efficiency concept (Su et al. 2013) that seeks to mimic natural biological systems by continuously recirculating and reprocessing materials and energy (Lieder and Rashid, 2016). As discussed by Winans et al. (2017), the circular economic model has evolved continuously since the 1970s, building on and encompassing a number of preceding ideas. It is deeply rooted in resource (eco-) efficiency concepts that advocate moving away from end-of-pipe solutions. For example, Stahel and Reday-Mulvey's (1976) vision of a 'loop economy' that returns durable products from cradle-to-cradle, and Pearce and Turner's (1990) argument for a shift from the 'resources-products-pollution' mode to a 'resources-products-regenerated resources' mode. Additionally, it incorporates 'limits to growth' and acknowledges that human industry relies on resources and services provided by the biosphere (industrial ecology) and therefore argues that consideration of the circular economy in isolation from biosphere services should be avoided (Erkman, 1997).

2.3.1 What is the circular economy?

The aim of the circular economy is to overcome the linear take-make-dispose mode of production and consumption through a circular system that maintains, for as long as possible, the value of products, materials and resources (Merli et al., 2018). In doing so, the circular economy encourages economic prosperity while ensuring environmental protection and social equality, both now and in the future (Kirchherr et al., 2017).

As highlighted in Figure 5, the aims of the circular economy mirror those of sustainable development. Defined in the United Nations (UN) report: Our Common Future, sustainable development is “development that meets the needs of the present without compromising the ability of future generations to meet their own needs” (Brundtland, 1987).

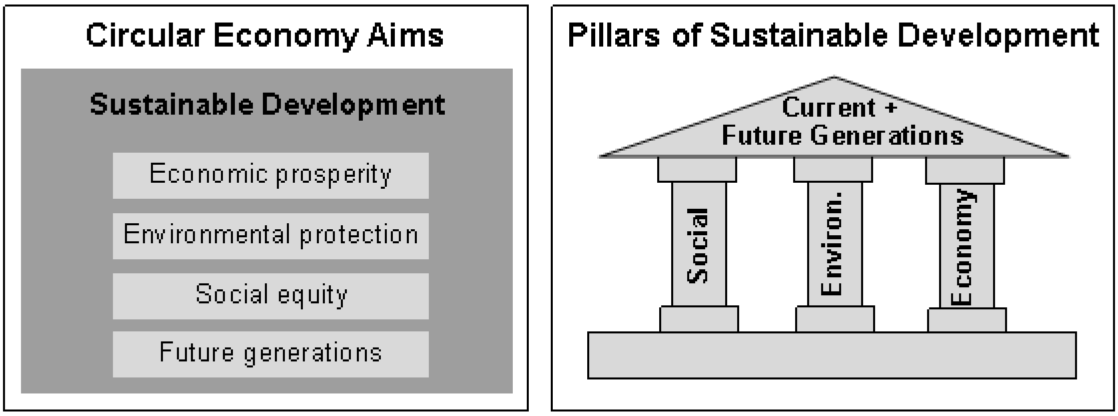


Figure 5: Comparison of circular economy aims (adapted from Kirchherr et al., 2017) with the three pillars of sustainable development (Brundtland, 1987).

The concept of sustainable development provides the foundation for the UN “2030 Agenda for Sustainable Development”, which is the leading global framework for international cooperation. Often framed as three pillars, the economy, society and the environment, sustainable development advocates the equal prioritisation of all three pillars with consideration given to both current and future generations (IISD, 2018; Brundtland, 1987). Based on two key concepts, sustainable development first identifies that the satisfaction of human needs and aspirations, prioritising the essential needs of the poor, as a major development objective. The second concept places limitations on technology and social organisation to ensure the ability of the environment to meet the needs of both present and future generations (Brundtland, 1987).

Like sustainable development, the circular economy has received increased international attention in recent years, with a consortium of global actors such as the UN and the World Economic Forum promoting the urgency of closing material loops (Reike et al., 2018). For instance, the UN has prioritised sustainable consumption and production within its 10-year Framework of Programmes (UNEP, 2015), a key component of which is the transition to a circular economy.

At a national level, several nations have already adopted the circular economy. China and Japan were the first Asian economic actors to introduce formal policies (Reike et al., 2018), with China adopting a version of the circular economy as a nationwide development strategy in 2002. China's version of the circular economy aims to promote sustainable urban development and to establish an equilibrium between urban and non-urban areas (Kalmykova et al., 2018). While the Chinese development strategy regards waste elimination and the reallocation of resources as positives, the aim of this strategy is to promote economic growth while avoiding material and / or energy shortages (Kalmykova et al., 2018).

In Europe, individual countries such as Denmark, Germany and the Netherlands have implemented circular economy initiatives, pilot schemes and policies (Reike et al., 2017). The promotion of the circular economy by such nations has underpinned strategies and legislation proposed at a supra-national level by the European Union (EU) (Reike et al., 2018; Gregson et al., 2015). The EU published the "Roadmap to a resource efficient Europe" in 2005 with the aim of becoming a recycling and recovery society by 2020 (Gregson et al., 2015; EC, 2005). This was updated with the publication of "Towards a circular economy: a zero-waste programme for Europe", which aims to establish a common and coherent framework to promote the circular economy across Europe (Domenech and Bahn-Walkowiak, 2019).

Despite widespread agreement for the need to transition to a circular economy, there is no common definition, or model, to describe the circular economy, or indeed a roadmap indicating how the existing linear model system would have to change during transition. In part, this is due to the evolving nature of the concept as well as different perspectives from various stakeholders, disciplines and sectors (Kirchherr et al. 2017).

Korhonen et al. (2018) argues that the concept of the circular economy has primarily been developed and led by practitioners, e.g. policy makers, businesses, consultants, and therefore misses a critical scientific dimension. Using the framework of sustainable development as a basis, Korhonen et al. (2018) critically evaluated the concept of the circular economy and suggested the following definition;

> *"Circular economy is an economy constructed from societal production-consumption systems that maximises the service*

> *produced from the linear nature-society-nature material and energy throughput flow. This is done by using cyclical material flows, renewable energy sources and cascading-type energy flows. Successful circular economy contributes to all the three dimensions of sustainable development. Circular economy limits the throughput flow to a level that nature tolerates and utilises ecosystem cycles in economic cycles by respecting their natural reproduction rates."*

Kirchherr et al. (2017) also recognises the use of sustainable development to frame a definition for the circular economy. Here, in a review of 144 definitions, the inclusion of all three sustainable development aspects was often found to be missing. For example, within the Korhonen et al. (2018) definition, economic prosperity is the primary focus followed by environmental protection, with very limited consideration of social equity or future generations (Kirchherr et al., 2017). To address these shortcomings, Kirchherr et al. (2017) proposed the following definition;

> *"An economic system that is based on business models which replace the 'end-of-life' concept with reducing, alternatively reusing, recycling and recovering materials in production / distribution and consumption processes, thus operating at the micro level (products, companies, consumers), meso level (eco-industrial parks) and macro level (city, region, nation and beyond), with the aim to accomplish sustainable development, which implies creating environmental quality, economic prosperity and social equity, to the benefit of current and future generations."*

While the definition given by Kirchherr et al. (2017) looks to change business models and include all levels of stakeholders, it does not identify functional aspects to delivering the circular economy. The Ellen MacArthur Foundation, a consultancy that has been influential in framing the circular economy (Reike, 2018), incorporates functional aspects with the following definition (EMF, 2018);

> *"Looking beyond the current take-make-dispose extractive industrial model, a circular economy aims to redefine growth, focusing on positive society-wide benefits. It entails gradually decoupling economic activity from the consumption of finite*

resources and designing waste out of the system. Underpinned by a transition to renewable energy sources, the circular model builds economic, natural, and social capital. It is based on three principles: (1) design out waste and pollution, (2) keep products and materials in use, and, (3) regenerate natural systems."

Rather than utilising a generalised definition, the complexity of the circular economy can be unpicked to understand the core concepts and principles that underpin it, and the measures, instruments and stakeholders that enable it.

2.3.2 Unpicking the circular economy: core concepts, principles and enablers.

Based on five core concepts and principles (Figure 6), the circular economy decouples growth from resource use, enhances resource efficiency, promotes systemic (transformational) change, employs life-cycle thinking and advocates sustainable consumption and production.

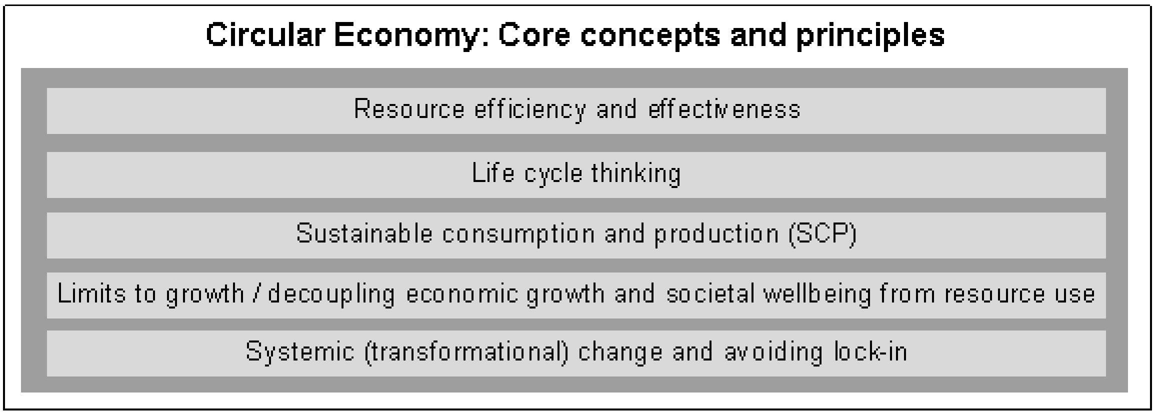


Figure 6: Core concepts and principles of the circular economy (based on Kirchherr et al., 2017).

Decoupled growth is where the mechanisms within an economy that create value do so without the consumption of finite resources (Kjaer et al., 2019). By increasing resource productivity, decoupled growth seeks to reduce the rate of resource depletion, and at the same time, reduce environmental damage, which can be either relative, i.e. less damage per growth rate, or absolute, i.e. reduced damage irrespective of growth rate (Kjaer et al., 2019; UNEP, 2011).

Resource efficiency seeks to achieve a more sustainable use of resources while minimising environmental impacts and improving economic competitiveness (Bundgaard, 2017). Resource efficiency can be defined at two levels. The first, as the ratio between useful output and inventoried flows. The second, as the ratio between intended effect and environmental impact. As such, resource efficiency is improved by reducing the amount of input resources used, or by reducing the level of environmental impact associated with the output (Bundgaard, 2017; Huysman et al., 2015). While this focuses on production, it is also important to consider resource efficiency during consumption, i.e. through operational efficiency. Here, products that are resource intensive during the use phase, e.g. high energy-consuming products such as white goods, are optimised. By supporting the user to reduce the demand for energy, operational efficiency also has the potential to minimise resource consumption (Kjaer et al., 2019).

Current eco-political discourse tries to address grand societal challenges, such as resource depletion and climate change, in a way that guarantees that life can go on as normal (Gorissen et al., 2016; Blühdorn, 2007). The circular economy requires a radical transformation of the system, with fundamental changes to cultures, practices and structures (Gorissen et al., 2016). Such systemic change should promote intergenerational equity and environmental sustainability to the top of the political agenda, and also to the core of personal and societal belief systems. However, this would require the major adjustment of social and financial systems and will incur immediate costs (McAlpine et al., 2015).

Life-cycle thinking is a sustainability management tool that considers all relevant supply chain interactions associated with a good, service, activity or entity (Pelletier, 2015). As a quantitative tool, it enables environmental, social and economic impacts to be assessed, and thus allowing resource efficient options to be chosen (Petit-Boix et al., 2017). It can also be used to understand and prevent unintentional shifting of burdens, where different kinds of impacts can appear at different stages of the supply chain and / or to different stakeholders (Pelletier, 2015).

To contribute towards environmental sustainability, sustainable consumption and production widens the focus of policy beyond pollution control to consider patterns of consumption (Geels et al., 2015). While the meaning of sustainable consumption and production is unclear, it jointly considers production and consumption activities and acts as an umbrella concept for a set of approaches including sustainable product service systems, eco-labelling, community grassroots innovation, and cleaner production (Geels et al., 2015; Lukman et al., 2016). Shaped by experts in areas of business development, consumer behaviour and systems innovation, sustainable consumption and production aims to provide sustainable solutions that reduce resource consumption by changing production and consumption patterns (Lukman et al., 2016).

To help realise the core concepts and principles of the circular economy, the employment of enablers (Figure 7) including measures and instruments to re-model business models, engage stakeholders, develop secondary markets, and promote technological innovation / investment, are required.

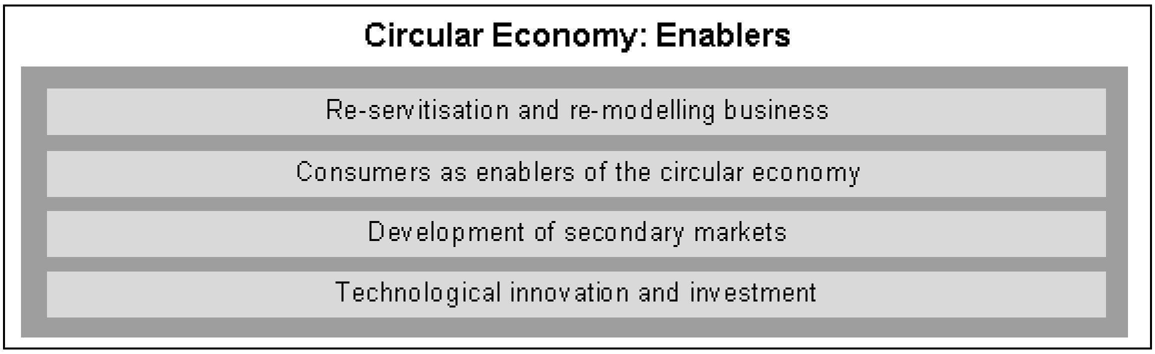


Figure 7: Key enablers of the circular economy (based on Kirchherr et al., 2017).

With alignment of the linear economic model with industrial capitalism, business models have a prominent role in the current production and consumption model. As such, the use of novel business models that are informed by appropriate social and moral foundations have a significant role to play as enablers to the circular economy (Kirchherr et al., 2017; Brennan et al., 2015). To change the way the consumer thinks about, and interacts with, products and services, business models can advocate re-servitisation, which also achieves greater alignment with the circular economy (Kirchherr et al., 2017; Brennan et al., 2015). For example, extending the lifespan of a product, a key component of the circular economy, would reduce unit sales and therefore negatively affect the on-going profitability of that product. Changing the business model to embrace re-servitisation, would create a profit stream through rental and maintenance agreements with consumers, making the importance of unit sales redundant and placing responsibility of maintaining and replacing products with the producer (Brennan et al., 2015).

New business models however, may be unviable if they lack the consumer demand to make them successful (Kirchherr et al., 2017). Indeed, even where there is a high willingness of consumers to act in line with the circular economy, consumer engagement is often low (Cerulli-Harms et al., 2018). A critical point due to the acknowledgment that consumer responsibility, and thereby engagement, is a crucial element of the circular economy. Indeed, consumers that choose to purchase products that are more durable, repair broken items, and engage with second-hand markets or rental / leasing schemes, are central enablers to the circular economy (Kirchherr et al., 2017; Cerulli-Harms et al., 2018).

As well as consumers, the circular economy depends of engagement across a wide spectrum of stakeholders. Su et al. (2013) note three levels (micro, meso and macro) of contributing stakeholders, all of whom are integral to the circular economy. Micro-level includes individual consumers, designers and producers, meso-level include community groups, individual sectors and industrial parks, and macro-level encompasses cities and regions (including local authorities, national government and regional administrations), co-operative networks and multi-national businesses (Su et al., 2013; Kirchherr et al., 2017).

As mentioned in light of consumer engagement, the development of secondary material markets is another enabler of the circular economy (Kirchherr et al., 2017). Developing markets for the trade and use of secondary materials (including recyclates, ashes, and waste-derived composts) encourage the use of such materials over virgin materials / resources (Schreck and Wagner, 2017). However, the viability of current global secondary markets, particularly the transboundary trade of recyclates, is negatively affected by volatile raw material and energy prices, logistics, geographies, export-import regulation, inconsistent (between countries) governmental policies and environmental targets, differing quality standards and varying degrees of law enforcement (Schreck and Wagner, 2017).

Technological innovation (and investment) is the final enabler of the circular economy (Kirchherr et al., 2017). Indeed, as de Jesus and Mendonça (2018) note, as technological innovation enabled the development of an industrial, carbon-intensive economy, it is plausible that transformative innovation can enable the transition to the circular economy. Furthermore, transformative innovation can increase efficiency and competitiveness, reduce existing environmental and societal impact, and create a chain of changes that stimulate complementary adaptations and destabilises the status quo to form a new techno-economic system (de Jesus and Mendonça, 2018). However, to overcome implementation barriers caused by economic and market limitations, it is key to support technological innovation with broad institutional change across markets, public policies and social practices (de Jesus and Mendonça, 2018).

2.3.3 That is the theory, but how does one implement the circular economy?

While the theoretical underpinnings and concept of the circular economy has been researched in detail, less focus has been placed on the implementation of the circular economy, and what is required in the transition from the current economic model. Intended to function as a fully regenerative closed-ecological economic system, the circular economy avoids, or minimises, both wastes and environmental impacts by encouraging the regenerative use of resources while sustaining, if not increasing, profitability (Lieder and Rashid, 2016). To enable this functionality, ranking of R-imperatives, which are resource-management options, within R-hierarchy provides an operationalisation principle for the implementation of the circular economy (Kirchherr et al., 2017; Murray et al., 2017). Within an R-hierarchy, the order of R-imperatives reflects the level of retained valued within a system. Significant variation has been found both in the R-imperatives themselves as well as the ranked R-imperative hierarchies.

In a review, Reike et al. (2018) identified 38 different R-imperatives terms[1]. Differences were also found in the number of R-imperatives used (between 3 and 10), the combination of imperatives, choice of terminology, and assigned meanings (the 38 different R-imperatives identified often have varying definitions), whether or not the imperatives were ranked, and in cases where they were ranked, their relative position (Reike et al., 2018). While efforts have been made to develop nuanced hierarchies employing a high number of R-imperatives, thereby providing an operationalisation principle that maximises resource value retention, inconsistencies remain (Potting et al., 2017; Reike et al., 2018). From a synthesis of Potting et al. (2017) and Reike et al. (2018), Figure 8 presents a hierarchy of

[1] R-imperatives identified by Reike (2018): re-assembly, recapture, reconditioning, recollect, recover, recreate, rectify, recycle, redesign, redistribute, reduce, re-envision, refit, refurbish, refuse, remarket, remanufacture, renovate, repair, replacement, reprocess, reproduce, repurpose, resale, resell, re-service, restoration, resynthesize, rethink, retrieve, retrofit, retrograde, return, reuse, reutilise, revenue, reverse and revitalize.

eleven common R-imperatives (R0 – R10) that increases alignment to the circular economy. Also shown is an existing application of an R-hierarchy, the waste hierarchy, which is discussed in further detail in Section 2.5.2.

Increasing circularity is characterised by R-imperatives of a lower number. For example, R0 to R3 all act to prevent the creation of waste and to enhance product utility. Achieving this by; designing out waste, thus refusing the use of excessive, hazardous or limited resources (R0), by sharing and repairing products to extend the lifespan of the product (R1), by using fewer natural resources in manufacture (R2) and by reusing products and refilling existing packaging (R3). With decreasing circularity, R4 to R9 provide options to manage discarded materials and products through the restoration of defective (R4) and outdated (R5) products, utilisation of components from discarded products in new products with the same function (R6) or with a different function (R7), reprocessing of materials to obtain quality secondary materials (R8) and recovering energy through incineration (R9). Finally, R10 provides an option to re-circularise the economy by retrieving materials from historic landfills.

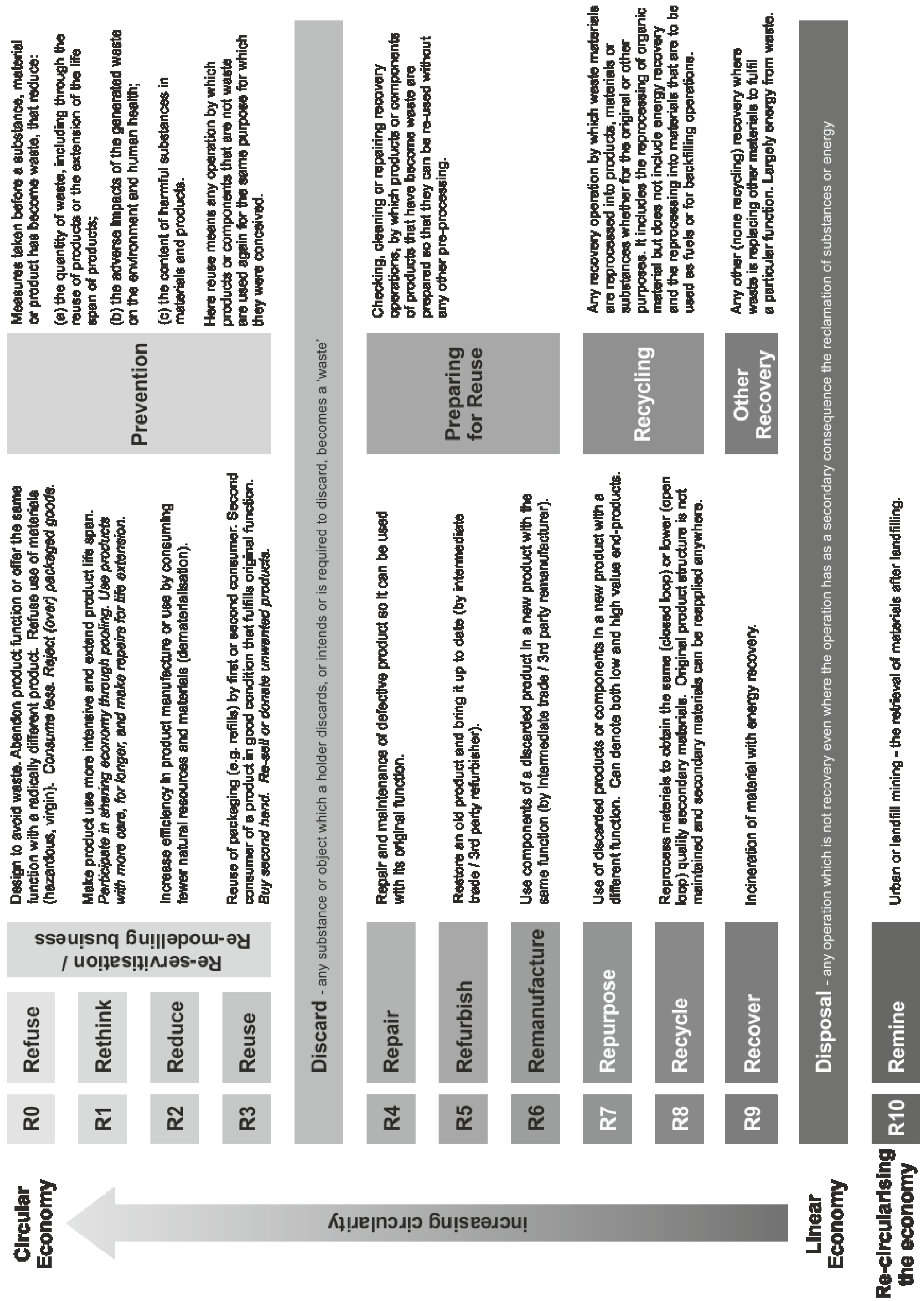


Figure 8: R-Imperatives (R0 – R10) needed in the transition to the circular economy, shown alongside the Waste Hierarchy terms (synthesised from Potting et al., 2017 and Reike et al., 2018).

To contribute fully to the circular economy, all stages of design, production, distribution and consumption should utilise R-imperatives (Su et al., 2013; Wysokińska, 2016). For example, dematerialisation (R2) and regeneration (R8) can be employed through eco-design approaches, and the lifespan of products can be extended through increased durability (R1), repair-ability (R4) and standardisation of components (R6) can be achieved through regenerative-design approaches (Lieder and Rashid, 2016; Wysokińska, 2016). To support the reuse and regeneration of products and materials, circular business models are required with mechanisms that place the financial and/or logistical responsibility for end-of-life products with the producer (EMF, 2017; Bocken et al., 2016; Wysokińska, 2016). Such mechanisms include extended producer responsibility and reverse logistics (EMF, 2017). Furthermore, changes to established business / consumption models can improve product utility and thereby resource efficiency (Stahel, 2016). Providing products through service agreements, such as pay-per-use, sees the producer retain responsibility and therefore incentivises resource efficiency and product utility above unit sales (Stahel, 2016; Tukker, 2015).

Similarly, changes to consumption behaviours such as increased consumer reuse, and the emergence of the 'sharing economy', in which underutilised assets are shared (or re-sold) through peer-to-peer interactions within community-based (online) services, may not only enable more efficient use of products but also deliver economic and social benefits (Cherry and Pidgeon, 2018; Martin, 2016). However, the extent to which these benefits are realised is unclear, with concerns that the sharing economy may lead to increased overall consumption (Cherry and Pidgeon, 2018; Martin, 2016).

2.3.4 Implementation sounds relatively straightforward, so how much success have we had so far?

While there is extensive academic and commercial interest in the circular economy, several gaps in knowledge remain, which restricts the widespread adoption of successful strategies (Babbitt et al., 2018). Indeed, the recent 'Circularity Gap Report' argues that progress towards adopting circular economy strategies is slow, with only 9% of global systems estimated to be 'circular' (de Wit et al., 2018). Given that the transition to a circular economy requires fundamental changes that involve a range of stakeholders and are disruptive in nature, the several barriers have been identified which restrict implementation. As detailed in Table 1, barriers can be connected to financial viability, structural systems, operational factors, technological advances and stakeholder attitudes and behaviours (Manninen et al., 2018; Moreau et al., 2017; Ritzén and Ölundh Sandström, 2017; Salemdeeb et al., 2016).

Table 1: Barriers to the circular economy (Manninen et al., 2018; Moreau et al., 2017; Ritzén and Ölundh Sandström, 2017; Salemdeeb et al., 2016).

Barriers	Examples
Financial *(Financial viability of CE strategies, from initial investment to ongoing funding for implementation and profitability.)*	Dominance of traditional business / economic models High capital expenditure / investment for new processes Limited funding Unclear financial benefits and costs, unknown return on investment or uncertain profitability
Structural *(Systems and models that CE strategies are based on, and the data required to inform / monitor implementation)*	Isolation of sectors, organisations and departments Lack of information / data (quality / availability) Difficult business decisions / poor future planning Lack of standardised systems / protocol / definitions
Operational *(Factors that may impact the operational integrity / success of implementation of CE strategies)*	Inappropriate / poor infrastructure Disconnected value chains and material cycles Limited / restricted / isolated markets Complicated / unclear policy and regulation Limited inclusion / verification of environmental and social costs / benefits
Technological *(Advances or innovation that change products or processes and introduce new materials)*	Poor product design Limited product / process integration Untested novel / new materials
Attitudinal *(Attitudes and behaviours of a range of stakeholders)*	Tendency towards risk aversion Inaccurate perceptions of sustainability and circular economy Poor consumer behaviour Institutional conventions (keeping the status quo)

Financial barriers generally concern the dominance of traditional business models. With a focus on increased resource efficiency, often cost-effectiveness underlies the success of circular economy strategies, with economic and territorial policies modifying conditions for profitability (Moreau et al., 2017). Here, a narrow focus on economic success fails to holistically integrate social and environmental goals, creating a conflict regarding the time and investment required to make systemic changes, and does not allow for uncertainty in revenue flows as businesses create new forms of value, based on previously externalised systems and services (Manninen et al., 2018; Ritzén and Ölundh Sandström, 2017). Therefore, to be successful, circular economy strategies need to go beyond economically viable material recycling, by incorporating social and institutional dimensions and addressing existing anthropogenic materials stocks, i.e. materials stocks created by humans, or human activity such as materials contained within landfills (Moreau et al., 2017).

Structural barriers to the circular economy are presented by the traditional siloed nature of industry sectors, organisations, and departments within organisations. Particularly where responsibility for implementation rests with different groups whom perform specific functions in isolation from others, leading to poor integration across systems (Ritzén and Ölundh Sandström, 2017). Furthermore, Jedelhauser and Binder (2018) note that while adoption of the circular economy has been discussed with regard to individual projects and the specific locations, this perspective neglects the spatial structure of both society (actors and institutions) and materials (infrastructure and resource flows / markets) that go beyond individual projects and specific locations. Effective integration is also limited by a lack of information. High quality data is required to conduct detailed system assessments and inform appropriate planning. However, due to the costs of systematic data collection, poor data availability and varying levels of disclosure, comprehensive data across the value chain is typically absent (Fan et al., 2019). For example, within the waste and resource management sector, data typically presents an incomplete picture with high aggregation levels, poor data frequency, and insufficient spatial dimensions (Niska and Serkkola, 2018). A lack of information may also limit opportunities to exploit potential resource stocks. For example, the practical feasibility of urban mining (extraction of materials from landfills) has been questioned due to a lack of data regarding resource availability, chemical or physical form, specific location, and level of accessibility (Bardi et al., 2016; Krook and Baas, 2013; Ongondo et al., 2015). This may be of particular relevance to developing a future strategic supply of Critical Raw Materials (CRMs) given the amount of e-waste in landfill sites (Ongondo et al., 2015).

To advance discussions concerning the circular economy, a shared understanding and common language is required. However, when comparing and contrasting the various frameworks that attempt to conceptualise the circular economy, interpretations can differ between stakeholders (Blomsma and Brennan, 2017). This lack of standardisation also extends to definitions, standards and protocols. In combination, isolation, lack of information and lack of a common language leads to poor dissemination between stakeholders and limits the ability to verify environmental, social, and financial benefits of circular economy strategies (Manninen et al., 2018). Whilst circular economy strategies look to improve product value chains and to close material cycles, Moreau et al. (2017) argues that this focus is too narrow and that other environmental and social externalities (e.g. clean air, fresh water, labour conditions) are often lacking. Furthermore, institutional aspects such as stakeholder participation and power distribution (from political and legislative processes), which determine private and social costs (such as labour intensity) affect the profitability and success of strategies (Moreau et al., 2017). In turn, this negatively affects decision making, where companies can lack the confidence to move toward circular business models due to poor levels of awareness (concerning the availability and economic benefits of alternative circular options) and insufficient information exchange (Saidani et al., 2019).

Collectively, structural barriers lead to poorly integrated systems (where supply chains are often highly connected but fragmented), and thereby result in operational barriers to the circular economy. For example, a lack of co-operation and collaboration within supply and distribution systems result in circular economy orientated policy being developed in isolation with little or no consideration of impacts or changes to other sectors (Ritzén and Ölundh Sandström, 2017; Salemdeeb et al., 2016). Likewise, poor data collection can also have a significant impact on infrastructure development where inaccuracies can result from the misinterpretation of current circumstances and poor projections of future scenarios (Mukhtar et al., 2016). For example, waste infrastructure planning is based on the quantification of waste flows and identification of existing options (Salemdeeb et al., 2016). If the quality or availability of such data is poor, planning options and thus decisions can be limited (Niska and Serkkola, 2018). This in turn can lead to provision of inappropriate infrastructure, where over-provision of the wrong type of infrastructure can present as much of a barrier as under-provision (Hubbard, 2017).

The development of secondary materials markets has also been promoted to close material cycles and enable the transition to the circular economy (Schreck and Wagner, 2017). However, global viability of secondary material markets has been limited by volatile raw material and energy prices, complex logistical and geographical concerns, inconsistent governmental policies, regulations and environmental targets (both between and within countries) and differing quality standards (Schreck and Wagner, 2017).

Indeed, the lack of harmonisation can restrict and isolate markets thereby limiting those that could enable the circular economy (Delgado et al., 2009). The evolution of policy instruments in response to technological advancements also requires consideration, with attention paid to the interaction between the negative externalities of pollution and the positive externalities of technological innovation (Leme et al., 2014; Luz et al., 2015). Jaffe et al. (2003) argue that policies targeting pollution reduction should also support technological change. For example, there is a case for combining environmental taxes with direct incentives if the signal from a single instrument is insufficient to promote innovation and adoption of beneficial technologies (Jaffe et al., 2005). However, to achieve an overall positive outcome, caution regarding the high level of policy coordination is needed, particularly when an instrument designed to address one issue is modified in light of another (Bennear and Stavins, 2007). Indeed, care must be taken to apply the correct amount of sanction, as under-regulation may lead to the careless management of resources and over-regulation (or regulation that is unclear) could lead to excessive bureaucracy, create unintended consequences and stifle innovation (Gharfalkar et al., 2015; Jaffe et al., 2005). Globally, this point is further exacerbated by the disparity of policy and regulation across nations. For example, waste policy in developed countries has evolved to encompass resource efficiency and other enablers of the circular economy, whereas in some developing nations effective waste management remains a challenge. Here, practices such as disposal in unregulated dumps and open burning are the norm and so development of sanitary (rather than progressive or towards the circular economy) waste management is the priority (Mukhtar et al., 2016; World Bank, 2018). As such, developing nations would benefit from the sharing of best-practice from developed nations (Cranston and Hammond, 2010).

Technological innovation enabled the development of the current industrial, carbon-intensive, linear economy, and it is presumed that innovation, by increasing efficiency and competitiveness, reducing environmental and societal impacts, and stimulating complementary adaptations across systems, can enable the transition to the circular economy (de Jesus and Mendonça, 2018). However, technological innovation, particularly product design and systems innovation, may also present several challenges. An example is the development of composites, where traditional materials such as metals, thermoplastics and organic fibres are combined to create new materials that have increased strength, reduced weight and / or enhanced durability (Rybicka et al., 2016; Yang et al., 2012). Due to the inherent heterogenous nature of composites and the lack of suitable facilities, the current recycling potential for these materials, or the potential to recover individual components, is limited (Yang et al., 2012). Even with respect to materials that are considered to be less complex, product design does not always consider eco-design / circular approaches that facilitate end-of-life management, particularly strategies that promote reuse, repair, recycling, etc. (Lieder and Rashid, 2016; Wysokińska, 2016). Here, the lack of integration between processes and coordination of different sectors (design / production and end-of-life management) creates another barrier in the transition to the circular economy.

The transition to a circular economy requires fundamental changes that involve a range of stakeholders and are disruptive in nature. However, major changes to products and systems (production / distribution / end-of-life management) driven by innovation and advancing technology have created stakeholder uncertainty regarding costs and level of adoption. Furthermore, concerns have been raised regarding the quality of materials and products that are designed with circularity in mind, i.e. made from recycled / secondary materials (Ritzén and Ölundh Sandström, 2017). Ritzén and Ölundh Sandström (2017) suggest that how stakeholders perceive, react and engage with the circular economy can be a limiting, or indeed prohibitive factor, where shallow understanding of circular economy principles may result in a tendency for risk evasion and promote small incremental steps rather than the systemic changes required.

In addition to general barriers to the circular economy, Jedelhauser and Binder (2018) note that, to date, the adoption of circular economy strategies has been discussed with regards to an individual project or at the specific location where they are implemented, e.g. at a city level. This perspective, it is argued, neglects the spatial structure of both society (actors and institutions) and materials (infrastructure and resource flows) that go beyond individual projects and specific locations, where this must be taken into account for successful implementation (Jedelhauser and Binder, 2018). Furthermore, Gorissen et al. (2016) argues that neither individual technological solutions nor single policy instruments can effectively solve grand challenges such as climate change, resource depletion and social inequalities. Indeed, many of the barriers highlighted above are common features of socio-technical systems. Comprised of a patchwork of physical technical assets and systems (hard infrastructure), and social systems that include institutions, users, rules and regulations (soft infrastructure) (van der Merwe et al., 2018), socio-technical systems are often structured by regimes where the status quo is institutionalised and socially embedded, i.e. markets feel secure in using established technologies. Furthermore, socio-technical systems are typically maintained by incremental changes along established developmental paths, which are often reinforced by the investment-experience cycle (Jedelhauser and Binder, 2018). These features, along with high investment costs, long technology lifetimes, and the prevalence of long-term contracts, often result in a high risk of lock-in, where a technology or process continues to be used when superior alternatives are available (Corvellec et al., 2013; Markusson and Haszeldine, 2009, 2010; van der Merwe et al., 2018). Thus, to realise the circular economy fully, as a way to address the grand societal challenges and overcome the barriers above, the intricate nature of socio-technical systems should be considered when developing circular economy strategies.

2.4 Socio-Technical Systems

2.4.1 What is a socio-technical system?

A socio-technical system can be conceptualised as a system that requires the utilisation of technology (i.e. machinery, raw materials, and plant infrastructure) along with a work-relationship structure that incorporates human operators (Cooper and Foster, 1971). In reality, socio-technical systems, such as those connected to energy, transport, agri-food, and waste sectors, are composed of a patchwork of hard infrastructure, such as physical technical assets and systems, and soft infrastructure, i.e. social systems including institutions, users, rules and regulations (van der Merwe et al., 2018; Geels, 2010).

Due to the structure of socio-technical systems, it is inevitable that a change made to one part of the system causes changes in other parts, therefore holistic consideration of the system is required (Challenger and Clegg, 2011). As such, any policy actions or project-specific decisions need to take in account inter-sectoral implications and be contextualised with overall national, supranational and international goals (Jedelhauser and Binder, 2018). Furthermore, due to the unlikelihood of any individual or single group understanding all the components parts of the system, proposed changes should engage with multiple stakeholders with a complementary range of knowledge and expertise (Challenger and Clegg, 2011).

2.4.2 General issues affecting socio-technical systems

Socio-technical systems are often structured by regimes where the status quo is institutionalised and socially embedded and are typically maintained by incremental changes along established developmental paths which are reinforced by the investment-experience cycle (Jedelhauser and Binder, 2018). These characteristics, along with the prevalence of long-term contracts and the long lifespan of technologies, result in a resistance to change and a high risk of lock-in.

Measures to incentivise preferred options are limited by technological lock-in. Here, the unintended consequence of placing preference on existing technologies may restrict the emergence and uptake of more sustainable strategies in the future. Lock-in is caused when technologies or strategies are introduced to address current issues (e.g. targets) but lack the flexibility to deal with future changes (Hughes, 1983). As highlighted by Corvellec et al. (2013), and Markusson and Haszeldine (2010; 2009), in addition to high investment costs, lock-in is exacerbated by;

- **accepting the status quo**, where markets feel secure in using established technologies,
- the **'experience-investment cycle'**, where experience in using a technology leads to more investment in the technology which leads to more experience etc.,
- operating within a **systems patchwork**, where individual processes and technologies are often part of a bigger system, and,
- the **long lifespan of technology**, where operational lifespans can span several decades.

Avoiding or overcoming lock-in is central for the transformation of systems, where avoidance is preferred, due to lock-in being very difficult to overcome once it has occurred. This requires the systematic promotion of alternatives, the social and political recognition of the importance of change, and/or an event or other development that forces change (Corvellec et al., 2013).

While avoiding technological lock-in is clearly a high priority, the "socio" element of systems also needs consideration. As noted by van der Merwe et al. (2018), too often emphasis remains on hard infrastructure in terms of resilience, development and maintenance, with less attention given to soft infrastructure. Grand societal challenges such as resource depletion and climate change are global, not directly visible and mainly concern the future. As such, these challenges suffer from uncertain cause-effect chains, diffuse causation and distant impacts (in terms of time and space) and thus depend largely on social movements and public opinion to promote change (Geels, 2010). Indeed, to transition towards sustainability, Jedelhauser and Binder (2018) argue that a fundamental shift in socio-technical systems is required where technological innovation and social change co-evolve.

In addressing these grand societal challenges, strategies must also be able to differentiate with respect to developmental status (Cranston and Hammond, 2010). For example, it could be argued that implementation of the circular economy in developed nations, which have high levels of societal awareness regarding sustainability and well-developed infrastructural and operational systems, only requires strategies to retrofit and adapt existing systems. In contrast, developing countries would require the installation of new infrastructure and operational systems if they do not yet exist, and for social awareness of sustainable issues to be developed.

2.4.3 Effectiveness of environmental policy within Socio-Technical Systems.

While the design of strategies is clearly important, it is equally important to achieve the desired impact through the effective implementation of policy instruments (Soderman et al., 2016). While policy has been successful in addressing environmental issues such as water pollution and smog, which are local, (relatively) immediate, and crucially visible and tangible to local communities, application to the grand societal challenges is more difficult (Geels, 2010). With one of the most advanced policy frameworks in the world, the EU is a leader in environmental policy (Wysokińska, 2016). However, with respect to socio-technical systems, environmental policy within the EU is limited by the “joint-decision” trap where status quo is favoured, and incremental policy is implemented, i.e. following route two of the policy evolution pathways, rather than innovative policy approaches that encourage systematic change (Domenech and Bahn-Walkowiak, 2019).

Existing environmental policy has been undermined by several stakeholder-related factors such as a lack of competent staff, ineffective administrative capabilities, incoherent or uncomprehensive written documentation, poor inter-organisational communication and support, a lack of cooperation, and competing priorities (Bailey and Rupp, 2005; Khan and Khandaker, 2016; Mosannenzadeh et al., 2017;

McTigue et al., 2018). Indeed, Bailey and Rupp (2005) found that due to competing priorities, eco-taxes could be counter-productive if a reduction in profitability leads to the de-prioritisation of environmental issues. Therefore, to understand and improve the success of environmental policy instruments, it is vital to consider stakeholder perspective (Bailey and Rupp, 2005). In particular, industry stakeholders have a valuable contribution to make towards understanding the strengths and weaknesses of environmental policy instruments (Bailey and Rupp, 2005).

So far, key socio-technical systems such as energy, climate, water and waste have embraced technological innovation to overcome the grand societal challenges (Ahmed et al., 2015; Austin and Macauley, 2001). However, realising the promise of new technology depends on several factors, including availability (cost and maturity) and ease of integration within existing systems (Ahmed et al., 2015; Austin and Macauley, 2001; Clausing and Holmes, 2010). Within technology development, the concept of readiness is used to limit the impact of these factors and aid the prioritisation of promising technologies for future investment (Armenakis et al., 1993; Mankins, 2009; Tetlay and John, 2009).

2.4.4 Introducing the concept of readiness and its application to Socio-Technical Systems.

The National Aeronautics and Space Administration (NASA) developed Technology Readiness Levels (TRLs) in the mid-1970s. Since their development, multiple sectors such as defence and energy have utilised TRLs (Mankins, 2009; Knaggs et al., 2015). Providing an expansion of research, development, and demonstration activities, TRLs allow a consistent assessment of technology maturity to be made, thereby enabling comparison between disparate and competing technologies. As shown in Table 2, there are nine TRLs, which can be grouped into six activities: basic research (TRL 1-2), feasibility studies (TRL 2-4), technology development (TRL 3-6), technology demonstration (TRL 5-7), (sub-)system development and demonstration (TRL 6-9) and system test, launch and operation (TRL 8-9) (Knaggs et al., 2015; Mankins, 2009).

Table 2: Technological, integration and systems readiness levels (based on Knaggs et al., 2015).

Technological readiness		Integration readiness levels		Systems readiness levels
System operational in IOE	9	#8 within system configuration (IOE)	1.00 - 0.90	Operations and Support
Actual system tested / qualified	8	IF proven in Nth application (IOE)		
System prototype demonstration	7	IF proven in 2nd application (IOE)	0.89 - 0.80	Production and Deployment
Pilot scale demonstration	6	IF proven at commercial scale (lab)		
Lab-scale system validation	5	Most elements demonstrate IF	0.79 - 0.60	Systems development & demonstration
Laboratory validation	4	Some level of IF demonstrated		
Proof of concept	3	Compatibility of technologies	0.59 - 0.40	Technology development
Concept / application formulated	2	Characterisation of requirements		
Basic principles observed	1	Need for integration identified	0.39 - 0.10	Concept refinement
IOE – Intended Operational Environment; IF – Integrated functionality				

While TRLs have proven useful in assessing the maturity of individual emerging technologies, they do not fully address the complexity of integrating multiple new technologies within a single system or integrating new technologies with existing technologies and systems (Knaggs et al., 2015; McConkie et al., 2012; Sauser et al., 2006). To address this, Sauser et al. (2006) proposed the use of Integration Readiness Levels (IRLs), which address the element of interaction, when a new technology needs to interface with another technology (either developing or mature). Useful in determining the readiness of individual technologies and technology interfaces, TRLs and IRLs are insufficient when applied to the use of multiple technologies within a single project, or the coordination of multiple processes across systems (i.e. within Systems of Systems) (Knaggs et al., 2012; McConkie et al., 2012). Instead, assessments should be expanded further to provide system-level maturity assessments, with for example Sauser et al. (2006) introducing Systems Readiness Levels (SRLs) to provide a metric (a function of

TRL and IRL) to measure the readiness of a system. The nine IRLs and five SRLs as shown in Table 2, with the latter being the product of a technology's combined TRL and IRL within the target system (Knaggs et al., 2015; McConkie et al., 2012; Sauser et al., 2006).

The concept of readiness has been applied to the energy sector in light of climate change targets. The Paris Agreement set the most recent climate change targets and was adopted in December 2015 at the UN Conference of Parties (COP21). Within this legally binding global climate change agreement, governments agreed a long-term goal of keeping the increase in global temperatures to well below 2°C (UNFCCC, 2016).

To meet these targets, significant reductions in CO^2 emissions are required, where the focus has been a reduction in the burning of fossil fuels (either by generating less energy or by using alternative non-fossil energy). However, reducing emissions through reducing fossil fuel combustion may negatively affect the (competing) priority of energy security, where the (un)likelihood of this is compounded further by the comparative low cost of fossil fuels. This conflict in priorities is evident in the desire of the energy industry to build new fossil-based plants (Markusson and Haszeldine, 2010). To address these conflicting priorities, many international organisations and nations (particularly high producers and consumers of fossil fuels) have identified 'Carbon Capture and Storage' (CCS) as a critical technology that would enable the continued combustion of fossil fuels during the transition to low-carbon energy systems (Consoli et al., 2017; Dahowski et al., 2017; Rohlfs and Madlener, 2013).

CCS comprises the capture of CO^2 from large point sources (such as sour natural gas reserves, chemical plants, and fossil fuel power plants), its transportation (via pipeline or shipping), and its long-term storage in geological reservoirs (Gibbins and Chalmers, 2008). While CCS component technologies have matured over the last three decades, deployment to date has been limited and CCS power plants are not yet commercially feasible (Consoli et al., 2017). Indeed, in 2017, there were only 21 large-scale CCS projects in operation or construction, only two of which were CCS power plants (Global CCS Institute, 2017). There are thus two related challenges facing the energy sector. Firstly, how to accelerate deployment of CCS thereby bringing costs down and achieving commercial viability, and secondly what to do about the construction of new fossil-based plants to meet energy needs in the interim. The concept of ‘readiness’ has been applied to both.

With respect to CCS deployment status, the Global CCS Institute has developed a CCS Readiness Index to allow assessment and tracking of country-level progress (Consoli et al., 2017). The CCS Index is based on four indicators; storage - assessment of potential geological storage sites and technical ability to store CO^2, legal - legal and regulatory frameworks such as environmental assessments, public consultations, and long-term liability, policy support - direct support for CCS, carbon pricing, research funding, and interest - fossil fuel production and consumption (Consoli et al., 2017).

With respect to the construction of new fossil-based plants, with an operational lifetime of around 30 to 40 years, a plant built now could remain in operation until 2050 or beyond (Graus et al., 2011). Accordingly, there is a significant risk that new fossil-based plants will persist as unabated emission sources for a long time, particularly if CCS does not become commercially viable (Markusson and Haszeldine, 2010). However, if CCS does reach commercial viability, two choices become available, (i) the premature closure of existing plants and replacement with CCS-plants, and (ii) retrofitting existing plants with CCS technology. With respect to premature closure, the significant capital investment in existing plants can cause reluctance to replace them before end-of-life (Corvellec et al., 2013). Thus, while some analyses indicate that replacement may prove more cost-effective than retrofitting (Rohlfs and Madlener, 2013), there has been a significant focus over the last decade on developing and applying the concept of ‘Carbon Capture Readiness’ (CCR), with the aim of future-proofing facilities built now to ensure they can accommodate a later retrofit of CCS. Here, future-proofing is defined as the process of anticipating the future and developing methods of minimising negative (and maximising positive) effects of shocks and stresses of future events (Rich, 2014).

A plant designed to be capture ready means it can be equipped with CCS technology while it is under construction or after it has been built, where retrofitting of capture ready plants is more cost effective (and therefore more likely to happen) than retro-fitting of non-capture ready plants (Rohlfs and Madlener, 2013). However, in addition to capture-ready plants, CCR also requires the consideration of infrastructure for CO^2 transport and storage (Markusson and Haszeldine, 2010).

This significantly reduces the investment cost to add CCS technology when compared with non-CCR plants and removes potential barriers such as insufficient space or unsuitable / non-existent reservoirs for storage (Graus et al., 2011). While these factors increase the complexity of any CCR regulation (Markusson and Haszeldine, 2010), they have already been identified and incorporated within EU policy, where Article 33 of the CCS Directive (EU, 2009) requires that new combustion plants (with an electrical output of 300 megawatts or more) comply with conditions of CCR. These conditions include the identification of a suitable (and available) geological storage site, assessments that demonstrate the technical and economic feasibility of CO^2 transport and retrofit for CO^2 capture, and the allocation of suitable space (reserved on the installation site) for the equipment necessary (EU, 2009). By adopting CCR, the energy sector can ensure that the security of energy sources for current requirements are not restricted as fossil-based plants can continue to be built and utilised.

As the energy sector faces challenges with respect to climate change targets, so too does another socio-technical system, the waste and resource management sector, where the new challenge is the transition towards the circular economy. TRLs have been used in the assessment of recycling options for glass and carbon fibre composite materials (Rybicka et al., 2016), industrial implementation of processes to recover Rare Earth Elements (REE) from magnets (Reimer et al., 2018), and approaches to prioritise recycling of end-of-life products through the development of a Recycling Desirability Index (Sultan et al., 2017). These studies have focused on the readiness of specific technologies and processes, and although the Rybicka et al. (2016) study noted the need to expand their assessment to system level to test conclusions concerning composite recycling options, the authors are unaware of any studies that use IRL or SRL assessment within the context of waste and resource management. The challenge for waste and resource management extends beyond the readiness of technologies to integrate into existing systems (as seen in the energy sector), but also the acceptance and involvement of society and other key stakeholders.

Indeed, while the focus on ‘technological’ aspects may be justifiable in CCR policy, as consumers are generally passive users of energy, the same is not true for the waste and resource management sector. Here, the public has a much more active role to play, with recycling and waste handling systems a feature of everyday life (Throne-Holst et al., 2007). Indeed, stakeholders have a critical role to play in ensuring the functionality of waste and resource management systems, where significant improvements can be achieved through the accumulation of small efforts from numerous stakeholders (Mukhtar et al., 2016; Throne-Holst et al., 2007). This is particularly apparent for the public whom are required to understand, in both the present and in the future, the connection between consumption and environmental degradation (Mukhtar et al., 2016).

2.5 Waste and Resource Management: A Socio-Technical System with a lot to give…

In collecting and managing wastes, the primary purpose of the waste and resource management sector has been to reduce harmful impacts to the environment and human health arising from indiscriminate disposal of untreated waste. In developed countries, this purpose has since evolved to encompass resource recovery aided by international, regional and national policy (Mukhtar et al., 2016; Calaf-Forn et al., 2014). Such policies advocate for more progressive waste management systems through increased resource efficiency, minimised waste generation and increased landfill diversion (Calaf-Forn et al., 2014).

2.5.1 Role of waste and resource management in the circular economy.

Waste and resource management has a vital role to play in the circular economy by maintaining (and recirculating) the value of materials and resources within the supply chain (Salemdeeb et al., 2016). Furthermore, as several barriers to the circular economy (particularly structural and operational) are attributed to the poor quantification and management of materials and waste, it has been suggested that circular economy strategies should include effective waste and resource management policy (Salemdeeb et al., 2016). Indeed, the EU is increasingly recognising the role of waste policy in supporting the transition from end-of-pipe waste management to efficient resource management, both within zero-waste and circular economy strategies (Soderman et al., 2016).

The transition to a circular economy is often viewed as synonymous with, or requiring a movement towards, ‘zero-waste’ (e.g. Ghisellini et al., 2016). Zero-waste can be defined in various ways including zero waste to landfill and zero waste emissions to land, sea and air, but generally requires progressive waste management and increased resource utility (Cole et al., 2014). While the two concepts are clearly complementary, they can be viewed as subtly different (Veleva et al., 2017), with implications for policy development for appropriate emphasis. For example, Veleva et al. (2017) argue that zero-waste approaches focus primarily on recapturing resources from waste streams, reducing consumption, and applying a life-cycle approach to product design, whilst the circular economy extends beyond this, by designing out waste and introducing innovative business models and collaborative platforms to continuously reuse materials. The circular economy also emphasises use of renewable materials and energy and places a stronger emphasis on the return of biological nutrients to nature. As such, pursuing zero-waste can be said to be characterised by incremental continuous improvements, whilst in comparison the circular economy is a transformative change. This subtle difference highlights the continued need to go beyond zero-waste by strengthening and enforcing instruments to adhere with circular economy principles (Jimenez-Rivero and Garcia-Navarro, 2017). An emphasis mirrored by EU policy initiatives that have placed increased prominence on circular economy models and the efficient use of wastes (Gregson et al., 2015; Smol et al., 2015; EC, 2016a).

2.5.2 Evolution of waste and resource management policy in the EU.

EU waste and resource management policy is based on three directives, the updated Waste Framework Directive (WFD) 2008/98/EC (EC, 2008), the Landfill Directive (LD) 1999/31/EC (EC, 1999) and the Packaging and Packaging Waste Directive (PPWD) 1994/62/EC (EC, 1994). Directives are introduced at a supranational level by the EU and define the minimum requirements that member-states must transpose into national legislation (Hughes, 2017).

Introduced as a tool to promote progressive waste and resource management, the waste hierarchy is a key component of all three directives (Van Ewijk and Stegemann, 2014). the waste hierarchy indicates an order of preference for the reduction and management of wastes, with top priority given to waste prevention, followed by (preparing for) re-use, recycling, recovery and as a last option disposal (Williams, 2015; Van Ewijk and Stegemann, 2014). The core concepts of the waste hierarchy (i.e. encouraging the prevention, recycling and processing of wastes) were first introduced in the 1975 Waste Framework Directive (75/442/EEC) (EC, 1975). Subsequently, the 1991 Waste Framework Directive (91/156/EEC) (EC, 1991) placed priority on the prevention and reduction of waste production and the five step waste hierarchy, as shown in Figure 9, was formally adopted in the 2008 updated WFD (EC, 2008).The waste hierarchy has been a key part of evolving EU waste and resource management policy ever since, and is perhaps one of the most established and consistent expressions of an R-hierarchy (as highlighted by Figure 8 in Section 2.3.3).

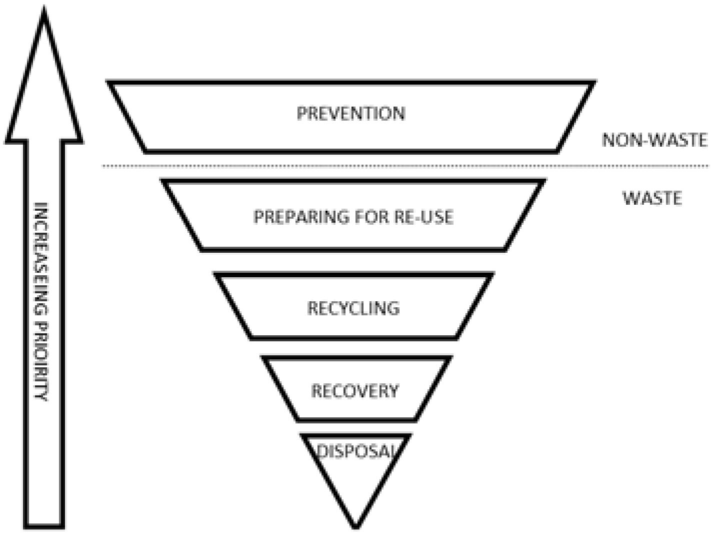


Figure 9: Waste hierarchy (based on EC, 2008)

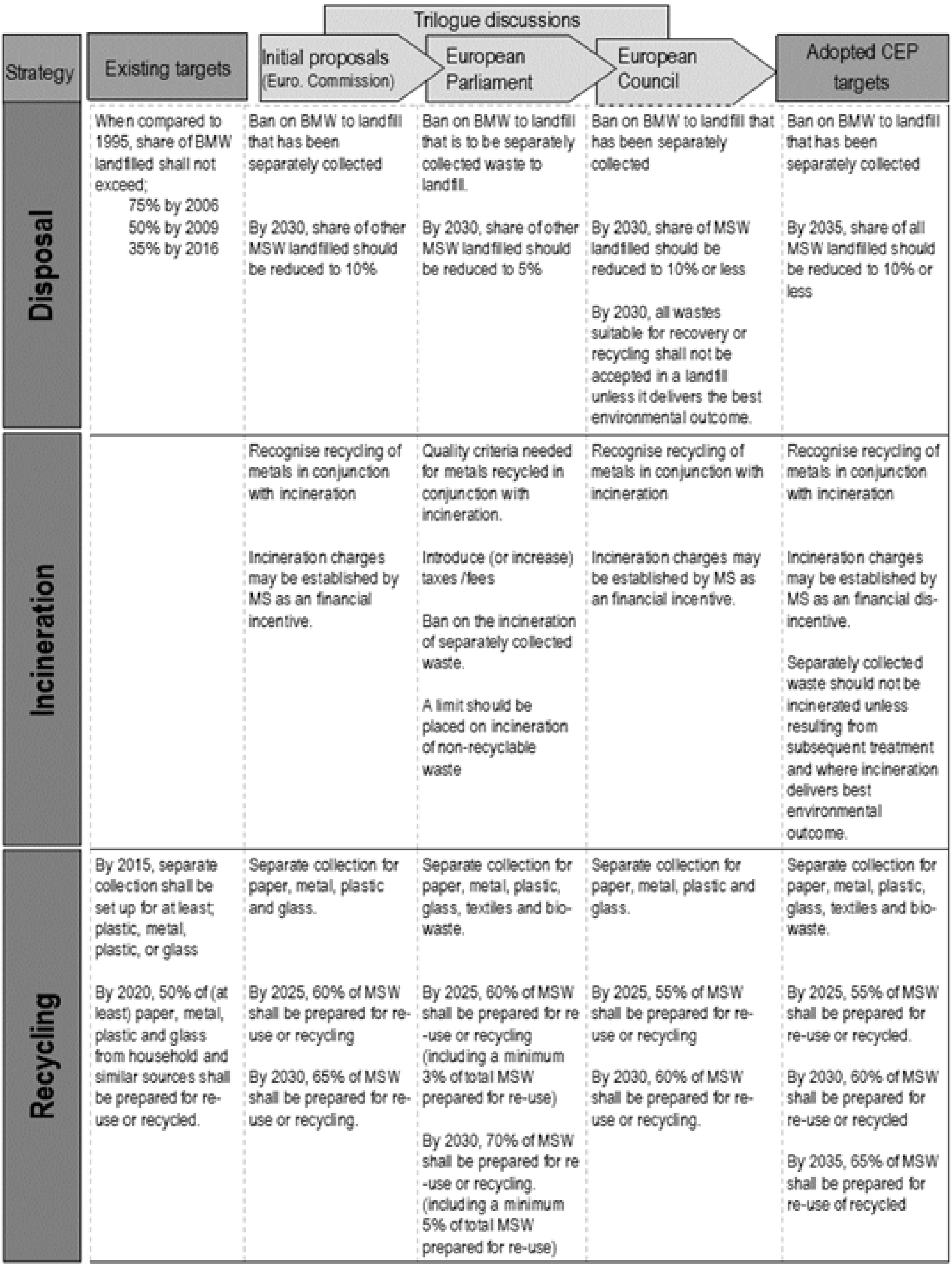
In addition to the waste hierarchy, the WFD defines what is considered a 'waste'[2], the LD aims to divert waste away from landfill and the PPWD promotes the recovery and recycling of packaging wastes (Gharfalkar et al., 2015; EC, 2008, 1999, 1994). In developing and standardising policy across its 28 member-states, Wysokińska (2016) argues that the EU has been a driving force in improving environmental standards internationally and is now driving the transition towards the circular economy.

In order to stimulate the transition to a circular economy, the EU published the Circular Economy Package (CEP) in 2015 (EC, 2015a). The CEP replaced previous initiatives such as the 'Roadmap to a resource efficient Europe' (2011-2013) and 'Towards a circular economy: a zero-waste programme for Europe' (2014-2015), which advocated for the efficient use of resources but focused almost entirely on waste management and related targets (EC, 2011, 2015a).

Prior to formal adoption, trilogue discussions between the European Commission (EC), European Parliament and European Council presented many variations on amendments proposed by the CEP (CEU, 2017a, 2017b). This process is

[2] The WFD defines waste as: "any substance or object which the holder discards or intends to discard or is required to discard" (EC, 2008)

summarised in Figure 10, highlighting the proposals put forward by the three official bodies and those finally adopted by the CEP.



		Trilogue discussions			
Strategy	Existing targets	Initial proposals (Euro. Commission)	European Parliament	European Council	Adopted CEP targets
Disposal	When compared to 1995, share of BMW landfilled shall not exceed; 75% by 2006 50% by 2009 35% by 2016	Ban on BMW to landfill that has been separately collected By 2030, share of other MSW landfilled should be reduced to 10%	Ban on BMW to landfill that is to be separately collected waste to landfill. By 2030, share of other MSW landfilled should be reduced to 5%	Ban on BMW to landfill that has been separately collected By 2030, share of MSW landfilled should be reduced to 10% or less By 2030, all wastes suitable for recovery or recycling shall not be accepted in a landfill unless it delivers the best environmental outcome.	Ban on BMW to landfill that has been separately collected By 2035, share of all MSW landfilled should be reduced to 10% or less
Incineration		Recognise recycling of metals in conjunction with incineration Incineration charges may be established by MS as an financial incentive.	Quality criteria needed for metals recycled in conjunction with incineration. Introduce (or increase) taxes /fees Ban on the incineration of separately collected waste. A limit should be placed on incineration of non-recyclable waste	Recognise recycling of metals in conjunction with incineration Incineration charges may be established by MS as an financial incentive.	Recognise recycling of metals in conjunction with incineration Incineration charges may be established by MS as an financial dis-incentive. Separately collected waste should not be incinerated unless resulting from subsequent treatment and where incineration delivers best environmental outcome.
Recycling	By 2015, separate collection shall be set up for at least; plastic, metal, plastic, or glass By 2020, 50% of (at least) paper, metal, plastic and glass from household and similar sources shall be prepared for re-use or recycled.	Separate collection for paper, metal, plastic and glass. By 2025, 60% of MSW shall be prepared for re-use or recycling By 2030, 65% of MSW shall be prepared for re-use or recycling.	Separate collection for paper, metal, plastic, glass, textiles and bio-waste. By 2025, 60% of MSW shall be prepared for re-use or recycling (including a minimum 3% of total MSW prepared for re-use) By 2030, 70% of MSW shall be prepared for re-use or recycling. (including a minimum 5% of total MSW prepared for re-use)	Separate collection for paper, metal, plastic and glass. By 2025, 55% of MSW shall be prepared for re-use or recycling By 2030, 60% of MSW shall be prepared for re-use or recycling.	Separate collection for paper, metal, plastic, glass, textiles and bio-waste. By 2025, 55% of MSW shall be prepared for re-use or recycled. By 2030, 60% of MSW shall be prepared for re-use or recycled By 2035, 65% of MSW shall be prepared for re-use of recycled

Figure 10: Amendments of targets under Circular Economy Package, with proposal given during trilogue discussions (based on EC, 2008, 2015b, 2015c; CEU, 2017a, 2017b).

Initially, amendments proposed by the EC placed a complete ban on the landfilling of biodegradable Municipal Solid Waste (MSW) by 2030, alongside a maximum landfill target for other MSW of 10% and an MSW recycling target of 65% by 2030 (EC, 2015b, 2015c). This was countered by more challenging targets proposed by the European Parliament (landfill target of 5% and recycling target of 70% by 2030), which were welcomed by the EC, as well as less demanding targets sought by the European Council, where some member states supported significantly lower recycling targets. However, this stance is not reflective of all member states, with some member states supporting the European Parliament with targets that are more stringent, providing a clear indication of the ambitions and future direction of EU waste and resource management policy. Under the auspices of the CEP, targets for landfill diversion and recycling were extended, where the final proposals introduced a total ban on all separately collected wastes, a maximum landfill limit for all MSW of 10% and a recycling target of 65% by 2035 (EC, 2015a, 2015b). Amendments to the LD, WFD, PPWD when applied to MSW, Construction and Demolition (C&D) waste and packaging waste are detailed in Table 3.

Table 3: Current EU waste management targets and the amendments set out in the Circular Economy Package.

Waste Stream	Existing Policies	Circular Economy Package
Municipal Solid Waste	Landfill Directive (EC, 1999)	Amendment (EC, 2018b)
	When compared to 1995 base year, the share of biodegradable municipal waste going to landfill may not be greater than 75% by 2006, 50% by 2009, and 35% by 2016.	Bans disposal to landfill of separately collected wastes and extends landfill diversion target to all municipal waste, where the share of municipal waste sent to landfill is limited to 10% by 2035.
	Waste Framework Directive (EC, 2008)	Amendment (EC, 2018d)
	By 2015, separate collection shall be set up for at least paper, metal, plastic and glass. Preparing for re-use and recycling of 50% of at least paper, metal, plastic and glass from household and similar sources by 2020.	Extends preparation for re-use and recycling to all municipal waste, with targets of 55% by 2025, 60% by 2030, and 65% by 2035.
Construction & Demolition Waste	Waste Framework Directive (EC, 2008)	Amendment (EC, 2018d)
	Preparing for reuse, recycling and other recovery such as backfilling of 70% of non-hazardous construction and demolition waste by 2020.	No extension to existing target but requires introduction of measures to promote selective demolition and removal of materials, and to establish sorting systems for at least wood, mineral fractions (concrete, bricks, tiles and ceramics, stones), metal, glass, plastics and plaster.
Packaging Waste	Packaging and Packaging Waste Directive (EC, 1994)	Amendment (EC, 2018c)
	By 2008 60% of packaging waste to be recovered, with a minimum of 55% and maximum of 80% to be recycled, and minimum recycling rates for specific materials as follows: wood: 15% plastics: 22.50% metals: 50% glass: 60% paper and board 60%	Removes the maximum and extends the minimum recycling rates for all packaging waste to 65% by 2025 and 70% by 2030, and extends the targets for specific materials as follows: wood: 25% and 30% plastics: 50% and 55% ferrous metals: 70% and 80% aluminium: 50% and 60% glass: 70% and 75% paper and board 75% and 85%

In addition to the revision of existing waste targets, the CEP also clarifies definitions regarding recovery and disposal (as shown in Table 4) in relation to waste-related targets and attempts to address broader aspects. Supported by other initiatives such as the “Thematic Strategy on the Sustainable Use of Natural Resources” (EC, 2005), the “Sustainable Consumption and Production Action Plan” (EC, 2008) and the “Integrated Product Policy”, the CEP acknowledges broader aspects of consumption and production (including the development of secondary materials markets) through mechanisms such as eco-design, eco-labelling, and green public procurement (EC, 2016b).

Table 4: Definitions of Recovery (including preparing for reuse, recycling and other recovery) and Disposal, as amended by the EU Circular Economy Package.

<table>
<tr><th colspan="2">Recovery</th></tr>
<tr><td rowspan="6">The principle result of a recovery operation is waste serving a useful purpose by replacing other materiasl which would otherwise have been used to fulfil a particular function, or waste being prepared to fulfil that function, in the plant or in the wider economy.</td><td>Prepare for reuse</td></tr>
<tr><td>Recovery operations that check, clean or repair products or components of products so they can be reused without any other pre-processing.</td></tr>
<tr><td>Recycling</td></tr>
<tr><td>Recovery operation where waste materials are reprocessed into products, materials or substances whether for orginal or other purpose. Includes reprocessing of organic matter but does not include energy recovery, reprocessing materials to be used as fuels or for backfilling* operations.</td></tr>
<tr><td>Other recovery</td></tr>
<tr><td>Any operation meeting definition of 'Recovery' but fails to meet specific requirements for 'Preparing for reuse' or 'Recycling'. Includes (co)incineration with energy recovery and backfilling* operations.</td></tr>
<tr><td colspan="2">*Backfilling is defined as a recovery operation where a suitable waste is used for reclamation purposes (in excavated areas) or engineering purposes (landscaping), where the waste is a substitue for non-waste materials (Article 11 (2) of Directive 2008/98/EC)</td></tr>
<tr><th colspan="2">Disposal</th></tr>
<tr><td colspan="2">Any operation which fails to comply with requirements of 'Recovery', even where the operation has a secondary consequence of the reclamation of substances or energy.</td></tr>
</table>

Furthermore, the CEP acknowledged that continued uncertainty surrounding the quality and quantity of secondary materials had restricted their use, thereby limiting resource recovery and diversion of waste from landfill (EC, 2015b, 2016a). For example, while utilising secondary aggregates in road construction would alleviate landfill pressures, perceived performance concerns and additional costs has hindered their use (Huang et al., 2007). In light of this, the CEP also supports the further development of secondary materials markets and the strengthening of quality standards such as End of Waste (EoW) (Bartl, 2015; EC, 2015b).

2.5.4 Introducing End of Waste criteria

Introduced in the updated WFD, the aim of EoW is to enable member states to achieve recycling targets by promoting a higher quality of secondary materials (Delgado et al., 2009; Van de Weil, 2009). It addressed issues concerning the lack of harmonisation between internal markets (John and Zordan, 2001; Delgado et al., 2009), poor user perception (Oyedele et al., 2014; Olivetti et al., 2011; Delgado et al., 2009), and administrative burdens (Delgado et al., 2009).

A lack of harmonisation within an internal market is caused by the independent development of regulatory frameworks that are often incompatible (Delgado et al., 2009). For example, within the EU, a material considered a waste in one member-state could be considered a non-waste in another (John and Zordan, 2001). In turn, this restricts the use of an internal market between member states, as the producers and users of recycled material stay within national markets to avoid administration or judicial costs (Delgado et al., 2009).

In addition to a lack of information regarding market availability, the uptake of secondary materials for use by the final consumer can be limited due to a perceived “low-quality” status, increased administration burden and higher associated costs (Oyedele et al., 2014; Delgado et al., 2009). With respect to quality, variability in composition has caused some secondary materials to be undervalued and underutilised as a raw material (Olivetti et al., 2011). With respect to the administrative burden, buyers of secondary materials would require environmental permits to handle and use the material, which can require a long and costly process. Thus, for materials with a clear route to re-use that are deemed to have little risk to human health or the environment, the application of waste legislation may result in an unnecessary administrative burden and act as an economic disincentive to utilisation (Delgado et al., 2009).

Specifically, the EoW introduced the conditions that must be met for a waste to be considered a non-waste, and therefore be subject to free trade and unrestricted use within the EU (Nash, 2009; Hjelmar et al., 2013). Article 6 (1) and (2) of the WFD (as shown in Table 5) set out four criteria for a waste material to obtain EoW status, where criteria (a) and (b) reduce the risk that the material is either discarded or stockpiled (Delgado et al., 2009), criteria (c) ensures the secondary material would be fit for use without any further processing or specific conditions that would not be required for the equivalent primary material (Zorpas, 2016), and, criteria (d) ensures that the secondary material does not require the application of waste legislation to protect human health or the environment (EC, 2015b).

Table 5: End of Waste Criteria, as reported by European Commission (EC, 2015b).

End of Waste Criteria	
(a)	**The substance or object can be used for specific purposes**
(b)	There is an existing market or demand for the substance or object
(c)	**The use is lawful (substance or object fulfils the technical requirements for the specific purposes and meets the existing legislation and standards applicable to products)**
(d)	The use will not lead to overall adverse environmental or human health impacts

EoW can be defined at different stages, depending on the original condition of the waste material (Delgado et al., 2009). First, materials that are easy to separate and require little or no processing fulfil the EoW criteria through quality of source waste (e.g. aluminium scrap). These waste streams are akin to primary materials. The second stage at which EoW can be considered is after processing (e.g. recycled gypsum). This requires that a waste stream be processed to a specific criterion before it is classified as EoW. Again, once this is achieved, the processed waste can be used akin to primary materials. Finally, the third stage considers EoW classification after a material has been processed into a consumer product for a specified end use (e.g. compost). These materials must follow factory production controls and be destined for use as intended.

Once a waste material has achieved EoW classification, it is no longer classified as waste in accordance with Article 6 (1) and (2) of the revised WFD. Ramifications of this include; no longer being subject to waste legislation and associated environmental and health protection measures, being regulated by product legislation, where it may be subjected to REACH[3] (if appropriate), and, under the definitions presented in Table 4, counting towards recovery (including recycling) targets (EC, 2008, 2015b).

Developed either centrally by the EC or by individual member states (EQual, 2013), existing EoW criteria published by the EC includes iron, steel and aluminium scrap, glass cullet and copper scrap. These are all examples of EoW criteria developed at stage one: quality of source and applied to high value materials with a high and consistent quality. Meanwhile, development of EoW criteria by individual member states has been limited, with only some member states such as the United Kingdom (UK) actively developing EoW criteria, and others questioning the legal value of implementing national EoW criteria. Here, it is noted that the current process to reclassify waste through EoW is lengthy and bureaucratic, which restricts the development of ways to treat or utilise waste materials (BIS, 2016; Van Acoleyen et al., 2015). Furthermore, the lack of uniformity and clarity in the use of EoW across member states has the potential to create waste market distortions; where cross border standardisation of national procedures are often time-consuming and difficult to achieve (Van Acoleyen et al., 2015). It can be argued that this may worsen in light of proliferation and duplication of EoW criteria (i.e. for the same waste streams) when developed by individual member states. While attempts have been made to address these issues, most notably through the IMPEL programme (a LIFE+ programme initiated by the EU regulatory network and EQual), utilisation by member states of tools and knowledge sharing platforms has been limited (EQual, 2015, 2013).

The CEP updated EoW by changing the terminology for criteria (a) from “the substance or object is commonly used for specific purposes” (EC, 2008) thereby allowing the use of EoW criteria for novel applications. To improve utilisation by member states, the CEP also promoted a shift in focus from developing new EoW criterion at EU level towards promoting implementation of existing ones and adopting criteria developed by member states (EQual, 2013; Zorpas, 2016, EC, 2015b).

The key messages of the CEP, such as embedding the creation of waste into product life-cycles, promoting green growth and green jobs, and advocating

[3] REACH is a European Union regulation concerning the Registration, Evaluation, Authorisation and restriction of Chemicals. (https://www.hse.gov.uk/reach/whatisreach.htm)

resource efficiency to reduce resource depletion and environmental degradation, are realised through elements such as introducing new methods of waste collection, more efficient techniques of recycling and better product design. However, Bartl (2018) argues that such elements are not conceptually innovative, and were in fact, introduced by Limits to Growth in 1972 (Meadow et al., 1972). This begs the question of why solutions identified four decades ago need to be re-packaged and re-introduced by the CEP. Here, it is argued that while the concepts remain up-to-date, the ideas have, and could still lack, substantial implementation which the CEP must address (Bartl, 2018). Furthermore, Van Ewijk and Stegemann (2014) and Gharfalkar et al. (2015) argue that, within the CEP, the limited specification of prevention, the absence of a distinction between open- and closed- loop recycling, and the lack of inclusion of other sectors could constrain dematerialisation and resource effectiveness.

2.5.5 Implementation of EU waste and resource management policy by member states, specifically the UK.

The multilevel governance character of the EU sees overarching objectives published centrally, with decisions regarding the approaches and instruments used to achieve these objectives resting with individual member states (Nilsson et al., 2012). There are several reported techniques by which EU policy is transposed into national policy. These include; “copy-out”, where the exact words and phrasing of the EU directive is used by the member state, “gold-plating”, where the member state goes beyond the minimum stated requirements, and “no gold-plating”, where the member state only includes the minimum required to adhere to EU policy (Anker et al., 2015). This degree of member state discretion has led to significant differences in national implementation of waste and resource management policy (Garcia Quesada, 2014).

Over the last two decades, EU directives have largely shaped UK environmental legislation, where the extensive use of secondary legislation to transpose EU law into domestic law is a notable feature of UK waste and resource management policy (Scotford and Robinson, 2013). Prior to EU legislation, the UK, like many member-states, had its own waste legislation driven by safety concerns rather than environmental considerations (Hughes, 2017). In providing the momentum to improve waste management, EU legislation lifted UK waste policy above the national party politics that previously hindered the development and implementation of a long-term strategy (UKELA, 2016; BP Collins, 2016).

The introduction of fiscal measures to facilitate the implementation of the LD is a long-standing example of UK waste and resource policy reacting to EU legislation. The UK introduced the Landfill Tax (UK LFT) in the 1996 Finance Act (HMSO, 1996) to encourage landfill diversion (the main objective of the LD) and the use of material recovery methods (Calaf-Forn et al., 2014; Morris et al., 2000). Later modified by the Landfill Tax (Amendment) Regulation 2009 (HMSO, 2009), the UK LFT is a regulatory incentive administrated by Her Majesty’s Revenue and Customs (HMRC), that applies differential tax rates to wastes disposed of to landfill in order to reflect the environmental burden of this disposal option (Calaf-Forn et al., 2014; Grigg and Read, 2001; Morris et al., 2000). It also defines inert (or inactive) waste, which qualifies for a lower tax rate, as non-hazardous (as described by the WFD) with a low Greenhouse Gas (GHG) emission potential (i.e. not biodegradable) and low polluting potential (i.e. contaminants unlikely to become mobile or leach). Any waste that does not conform to these criteria is classed as active and is liable for the standard tax rate (HMRC, 2016a).

In accordance with Section 42(2) of the Finance Act 1996(a), a definitive list of materials that were deemed to meet the definition of inert waste (for the purposes of setting the UK LFT rate and based on well characterised properties) was published. Originally delivered through the Landfill Tax (Qualifying Materials) Order 1996 (QMO), and updated in 2011, the materials listed include; naturally occurring materials (rocks, sand and soils), low activity processed materials (glass, ceramics or concrete), processed or prepared minerals (silica, mica or clay), furnace slags, ash, low activity inorganic compounds, calcium sulphate, and calcium hydroxide (including brine) (HoC, 2011, 1996).

When first introduced, the UK LFT rates were £2 /tonne for inert waste and £7 /tonne for active waste, thus with gate fees of around £5 to £15 (ENDS, 1994) total disposal costs remained relatively low. As such, the UK LFT provided little financial incentive for diversion and had minimal effect on the amount of waste being disposed to landfill (Martin and Scott, 2003). To address this legislative failure, the UK LFT escalator was introduced (HM Treasury, 1999; Martin and Scott, 2003), where the price of landfilling active waste increased by a fixed amount each year from 2000 to 2014. Since 2015, both the active and inert tax rates have been index linked (HMRC, 2016b), standing at £84.40 /tonne for active waste and £2.65 /tonne for inert waste in 2016/17 (HMRC, 2016a). Although gate fees have also increased (partly reflecting improved landfill management practices) they have been relatively stable since 2008, with a mean of £22 /tonne in 2016 (WRAP, 2009, 2017). Thus, for active waste the tax liability now clearly exceeds other disposal costs, and the total disposal cost (around £106 /tonne) is considerably higher than that for inert waste (around £25 /tonne).

While fiscal instruments such as the Landfill Tax have aided a transition away from high landfill dependency (Pomberger et al., 2016), the UK is experiencing a plateau in progress, potentially caused by the “no gold-plating” approach of transposition. As such, the development of new measures that manage resources rather than waste are now required to maintain the momentum of positive change and to align with more recent EU waste and resource management strategies such as the CEP.

Although the UK is currently negotiating its withdrawal from the EU (termed “Brexit”), it is expected that the CEP will be transposed into UK law. Once the UK has fully withdrawn from EU membership, it will no longer be obligated to transpose or adhere to EU directives. While the official withdrawal date is [at time of writing] the 29th March 2019, a transition period extending to 31st December 2020 has been agreed, during which EU law “shall be applicable to and in the UK” (EC, 2018a). Thereby, the UK will be obligated to transpose the amendments that were introduced by the CEP (EC, 2018b-d) in 2018, with the requirement that transposition is completed within 18 months (i.e. mid-late 2020). As noted above, current UK environmental law is highly dependent on that of the EU, where the UK will convert the existing body of EU environmental law into domestic law on ‘exit day’ through a blanket transposition under the Withdrawal Bill (European Union (Withdrawal) HL Bill (2017-19) 79). However, after the end of the transition period the UK would not be obligated to adhere to the CEP, where UK governments could act to repeal or amend the transposed domestic law (BP Collins, 2016; UKELA, 2017). This leads to the question of how UK waste and resource management will develop in the absence of the long-term vision and strategy provided by the EU (Bees and Williams, 2017). Current commentary on post-Brexit waste policy suggests that in the short term the UK would continue to apply existing EU legislation and strategy (Burges Salmon, 2016; BP Collins, 2016). While the current government has made commitments, within its 25-year environment plan, to improve the environment and thereby “leaving it in a better state than we found it” (Defra, 2018), in the medium to long term it is difficult to predict whether successive UK governments would maintain these commitments.

Therefore, there is uncertainty regarding ongoing compliance with current and successive EU legislation, where the UK could continue to make changes to align with future amendments, look to go beyond them, or maintain the current status quo, with the risk of being left behind (Burges Salmon, 2016).

Other potential implications of Brexit for waste and resource management in the UK, and for other EU member states, relate to the cross-border movement of wastes (House of Lords, 2017; UKELA, 2016, 2017). Gibraltar (a British overseas territory) is completely reliant on Spain for its waste management (both collection and treatment) and the Republic of Ireland exports 40% of its hazardous waste to the UK due to the lack of capacity in local treatment facilities (McGlone, 2018). The UK also exports a significant tonnage of waste derived materials to other EU member states. Indeed, exports of waste derived fuel to European countries have increased from zero in 2010 to over 3 million tonnes in 2016 (DEFRA, 2017; UKELA, 2016). Likewise, due to limited domestic processing capacity, exports of recyclable materials have risen from around 8 million tonnes in 2002 to around 14 million tonnes in 2015 (DEFRA, 2017), where around a quarter of sorted waste materials are sent to northern European countries which have an overcapacity in processing facilities (House of Lords, 2017).

Post-Brexit, the movement of waste between the UK and EU countries must adhere to the European Waste Shipment Regulations (EWSR) (EC, 2006). Under the EWSR, the import of waste is allowed from a third (non-EU) country that is party to the Basel Convention on the Control of Transboundary Movement of Hazardous Wastes and their Disposal (the Basel Convention) (UNEP, 1989). However, export of waste for disposal or mixed municipal waste for recovery to a third country is prohibited, unless it is both a party to the Basel Convention and a member of the European Free Trade Association (EFTA). Furthermore, imports and exports of waste between the UK and the EU will most likely become subject to border checks and depending on the outcome of negotiations could become subject to tariffs (EC, 2018a), with the risk that such shipments become financially unviable (House of Lords, 2017).

The future status of the UK with respect to the Basel Convention (an international agreement ratified jointly by the EU and the UK) is uncertain. Analysis indicates that the effect of Brexit on such “mixed agreements” is somewhat ambiguous, with some analysts concluding that they will have to be renegotiated, and others adopting the position that the UK will remain bound by them post-Brexit (UKELA, 2017). Nonetheless, while the status of mixed agreements remains to be clarified, the UK government has expressed the view that the UK is a party in its own right and will continue to be bound by such agreements post-Brexit (House of Lords, 2017).

The UK joining the EFTA post-Brexit has been posited as a potential option, in which case waste exports from the UK to the EU (and vice versa) could continue with respect to EWSR, however access to the single market (to avoid import / export tariffs) would require the UK to continue to adopt the relevant evolving EU acquis. Furthermore, for any recovery of waste generated by EU member states and exported to the UK, the EU member state will only be able to count that waste towards fulfilment of EU targets if the treatment conditions are equivalent to the requirements of applicable EU directives (EC, 2018d). All the Brexit related uncertainties regarding the future of waste management in the UK are further complicated by the differing positions of the devolved nations.

The devolution of power in the UK allows the four home nations (England, Scotland, Wales and Northern Ireland) to manage waste and resources (and other environmental policy areas) within their own boundaries while contributing to overall UK objectives. This has led to the introduction of different strategies by the four nations that differ slightly in approach in a number of environmental policy areas. As previously discussed, overarching UK waste policy has evolved since the 1990s, where alternative waste management strategies have been promoted by environmental supranational policy and financial pressures (Gray, 1997). UK-wide studies, such as Ajayi and Oyedele (2017), Bulkeley and Gregson (2009) and Coggins (2001), have focused on particular aspects of waste management such as construction waste, household waste generation, and packaging waste, respectively. Within the context of environmental issues and/or waste related targets, these studies highlight the need for closer engagement with the primary unit of consumption, i.e. households (Bulkeley and Gregson, 2009; Coggins, 2001) and corroboration of government initiatives with input from professionals (Ajayi and Oyedele, 2017).

However, there is a paucity of literature that compares the policies and strategies of the four devolved nations. The analysis of England's policy has been completed in light of climate change targets (Papageorgiou et al., 2009) and the WFD

(Falmer et al., 2015). Again, these studies have focused on one aspect of waste management: energy recovery from waste and household waste, respectively. There have been studies that assess both the waste management strategies of England and Wales. Here, consideration of waste policy within England and Wales has been confined to assessing implementation of local authorities, with respect to household food waste collection (Bees and Williams, 2017) and in light of established strategy – here the Waste Strategy 2000 (England and Wales) (Parfitt et al., 2001). While Parfitt et al. (2001) provides no explicit comparison of England and Wales with respect to implementation, Bees and Williams (2017) highlight significant policy and administrative differences and argue that England has no clear policy direction while Wales presents an integrated local and national approach.

Perhaps the most comprehensive study comparing the four devolved nations is Scotford and Robinson (2013). Based on an evaluation of primary and secondary environmental legislation, Scotford and Robinson (2013) argue that within the UK, Wales and Scotland are currently providing the most innovative legislation developments. This aligns with Falmer et al. (2015) (and Bees and Williams, 2017) who argue that England lacks clarity and direction regarding waste policy due to changes in policy, practice and infrastructure not aligning with the waste hierarchy (a key component of EU waste policy) and conflicting legal and financial factors. As well as a limited number of studies comparing policies between the four devolved nations, those available have been in light of general environmental issues, waste related targets or pre-CEP policy. **Thus, consideration and / or inclusion of circular economy principles by devolved waste policy is yet to be explored**.

2.5.6 What level of success has EU waste and resource management policy achieved across its member states?

Under the previous policy regime (pre-CEP), the continued promotion of the waste hierarchy, in combination with stringent landfill diversion targets, led to a marked change in the management of MSW. The EU defines MSW as household waste or waste from other sources that is similar in composition (EU, 2015). While MSW only constitutes 7-10% of total EU waste arising, the management of MSW is considered an excellent indicator of the quality and efficiency of a member state's waste and resource management strategy, this is because it is one of the most complex waste streams to manage (EU, 2015).

Within Europe, the management of waste has improved greatly over the last four decades. By 2015, six member-states (Switzerland, Sweden, Denmark, Netherlands, Norway and Austria) were disposing less than 6% MSW to landfill, and Germany reached a recycling rate of 66% (Bartl, 2018). Indeed, to date, northern high-income member states such as these have been the most successful in improving MSW management practices and diverting waste from landfill in line with EU waste objectives. Over the last two decades this has been through the accomplishment of “easy gains” and by targeting the “low hanging fruit” (Mihai and Apostol, 2012).

Focus on near term targets has led to significant investment in advanced technologies such as Material Recovery Facilities (MRFs), Mechanical Biological Treatment plants (MBTs) and incineration. As such, the removal of recyclable materials, such as glass, high-grade plastics, and metals, has become routine across many member states (Beccali et al., 2001; Santibanez-Aguilar et al., 2013). Likewise, combustibles (e.g. low-grade plastics and textiles) are separated and used as refuse derived fuel (Násner et al., 2017; Vountatsos et al., 2016), while biodegradable materials (e.g. food and garden wastes) are removed and then composted or used for energy generation (Santibanez-Aguilar et al., 2013). Generally, this has been achieved through source segregation and in more recent years through technological separation in MRF and MBT plants (Cook et al., 2015; Vountatsos et al., 2016). Such approaches are commonplace across a range of waste streams including the management of C&D wastes.

Furthermore, fiscal incentives such as landfill taxes have also driven diversion away from landfill. For example, the UK LFT has been applied to all non-exempt wastes, with the standard rate typically applied to MSW and hazardous waste, and the lower rate typically applied to C&D waste (Conran, 2017). While sufficient data is not available to assess the impact of the UK LFT on all waste streams, it is available for MSW (Figure 11). For this waste stream, the UK LFT escalator (as discussed in Section 2.5.5) incentivised a dramatic reduction in landfilling of around 50% between 2000 and 2013, with a concomitant fivefold increase in other waste treatment methods (Eurostat, 2017; HMRC, 2016a).

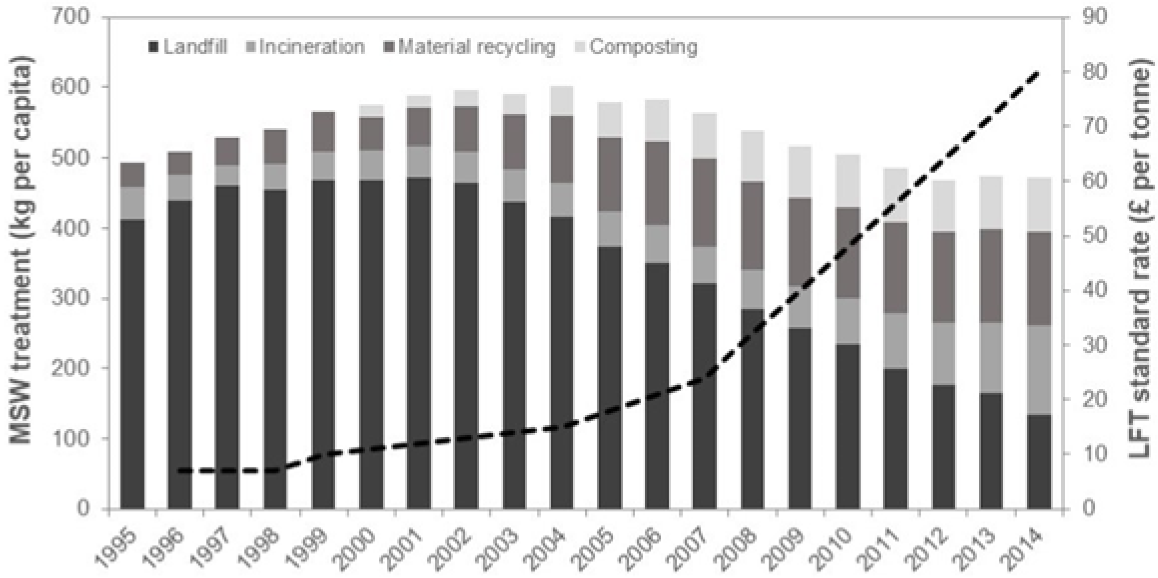


Figure 11: Impact of the UK landfill tax on the management of municipal solid waste. The landfill tax liability for standard-rated materials is from HMRC (2016a). Waste management data are from Eurostat (2017).

It is argued that focus on near-term targets, in particular landfill diversion, has limited the utilisation of the waste hierarchy where a one-step improvement (i.e. from dependence on landfill to recovery operations) has been commonplace. Indeed, while advanced processing methods have delivered gains in material and energy recovery, they have not delivered (and cannot deliver) full recovery, where landfill disposal remains the preferred option for residual waste streams (Beccali et al., 2001; Santibanez-Aguilar et al., 2013).

2.5.7 What happens to the remaining residual waste materials?

In addition to a reduction in the amount of waste disposed of to landfill, another consequence of technological advancement has been the growing proportion of residual wastes.

With diminishing returns, it is becoming more difficult to achieve further landfill diversion through enhanced recycling, as such, incineration (with or without energy recovery) has increasingly been employed in order to achieve landfill diversion targets (Eurostat, 2017). The advantages of incineration include the ability to harness the energy content of the waste alongside a dramatic reduction in mass and volume. However, while the mass of waste is typically reduced by ca. 80%, there remain a number of solid residues, the most substantial being incinerator bottom ash (MSW-IBA).

MSW-IBA is a grey to black granular, agglomerated material. Typically comprising of a heterogeneous mix of brick, concrete, silicate-phase glass, unburnt organics and clinker (stony residue from furnaces), it can also contain cullet, tiles, rusty nails and ceramic pieces with a varying abundance of ferrous and non-ferrous metals (Bourtsalas et al., 2015; Chiang et al., 2012). The elemental composition varies considerably, dependant on waste input and combustion unit type. The most common elements are calcium, silicon, aluminium, iron, sodium and manganese, where heavy metals such as antimony, arsenic, barium and beryllium may also be present (Margallo et al., 2015). The presence and relative concentration of elements strongly reflects waste inputs, for example, high concentrations of aluminium and iron may indicate beverage cans, and high levels of silicon and antimony indicate glass products and batteries, respectively. For a detailed physicochemical analysis of MSW-IBA, see Dou et al. (2017).

Due to the heterogeneous nature of MSW-IBA, it is classified within the European Waste Catalogue (EWC) as a mirror entry, whereby the material may be hazardous or non-hazardous (EA, 2015). Here, attention is given to MSW-IBA classified as non-hazardous. MSW-IBA has historically been disposed of to landfill, which is less than optimal in terms of resource conservation and environmental safety (Chen and Lo, 2015). Furthermore, landfill capacity is decreasing, and the economic costs of landfilling, such as gate fees and environmental taxes, are increasing. Current management strategies for MSW-IBA therefore look to realise the recovery potential for resources such as metals and aggregates (Cheeseman et al., 2005; Allegrini et al., 2015).

It is now common practice for ferrous and non-ferrous metals to be recovered using magnetic and eddy-current separators (Allegrini et al., 2014, 2015). Accounting for up to 10% by weight of MSW-IBA, metal fragments can differ in size and quality, which in turn affects recycling efficiencies (Allegrini et al., 2014, 2015). Whereas the recovery of ferrous metals is typically around 80%, for non-ferrous metals this can be as low as 30% (Allegrini et al., 2014; Boesch et al., 2014), although the use of advanced systems can increase this to 70% (Biganzoli et al., 2013; Grosso et al., 2011).

The removal of metal fragments increases the quality of MSW-IBA for utilisation as an aggregate, where another commonly employed treatment is sieving to produce size separated materials with good geotechnical characteristics (Karagiannidis et al., 2013). However, the chemical and mineralogical characteristics of the residual MSW-IBA, particularly the alkalinity, can result in unwanted instability and leaching (Dou et al., 2017; Lancellotti et al., 2013). To overcome this issue and to achieve suitable stabilisation, further processing is typically required (Arickx et al., 2006; Cheeseman et al., 2005; Lancellotti et al., 2013). This is often achieved through weathering or natural aging, where the exposure of an open stockpile to the atmosphere promotes carbonation (where atmospheric CO^2) is absorbed by the alkaline MSW-IBA) resulting in the precipitation of carbonate minerals such as calcite and a reduction in pH (Chimenos et al., 2000; Yao et al., 2010). Although the time required completing carbonation through natural aging (such that the leaching potential is minimal) is somewhat lengthy (up to three months), the use of CO^2 enriched atmospheres has the potential to reduce this timescale to two weeks (Margallo et al., 2015).

The most common end use for MSW-IBA is as an aggregate, where the physicochemical characteristics of treated MSW-IBA are similar to those of natural aggregates. Indeed, the use of MSW-IBA has been successfully employed as a partial substitute in numerous basic construction applications (Ahmed and Khalid, 2011). For example, it has been shown that MSW-IBA can replace without detrimental effect; up to 20% of natural aggregate as a sub-base in road construction (Birgisdóttir et al., 2006), up to 25% of clinker used in cement production (Margallo et al., 2014), and up to 15% cement in low-strength concrete production (Jurič et al., 2006).

In addition to generating income from product sales as a secondary aggregate, the utilisation of MSW-IBA as a construction material has two further advantages; the reduction of waste landfilled and the substitution of natural resources (Margallo et al., 2015). Diverting significant volumes of MSW-IBA from landfill would reduce the economic and environmental costs of landfill disposal (Birgisdóttir et al., 2006; Olsson et al., 2006). In addition, substituting raw materials with MSW-IBA avoids the energy use and other environmental costs associated with the extraction and processing of natural resources, instead allowing for the protection and conservation of mineral stocks (Olsson et al., 2006). Indeed, the use of MSW-IBA as an alternative for aggregates in construction applications is particularly attractive given an increasing demand for construction materials and the declining availability of natural aggregates (Abbà et al., 2014).

A number of alternative processing and application options have also been explored in the literature and are summarised in Table 6. These include the potential for recovering rare earth elements (Allegrini et al., 2014; Funari et al., 2016) and other CRM's (Funari et al., 2015), use as a growth substrate (Bates et al., 2015), use in other construction materials such as pyroxene ceramic tiles (Barbieri et al., 2002; Schabbach et al., 2012), alkali activated cements (Garcia-Lodeiro et al., 2016; Lancellotti et al., 2013, 2015), and aerated concrete (Song et al., 2015), in addition to use in hydrogen gas production (Saffarzadeh et al., 2016; Biganzoli et al., 2013), or as a purification agent (Ducom et al., 2009; Liu et al., 2014). However, as these do not yet represent substantial utilisation pathways they are not discussed further here.

While the generation, treatment and management of IBA from the incineration of MSW has been extensively discussed (see Dou et al., 2017; Margallo et al., 2015 and references therein), **the production and utilisation of MSW-IBA as a secondary material in the context of evolving EU policy and practice warrants further exploration**. For example, continued investment in incineration infrastructure to meet current targets could (by lacking the flexibility to change, incurring high investment costs and being built to operate over a long life-span) restrict the emergence of more sustainable solutions required to address future changes, thus resulting in lock-in (Hughes, 1983, Corvellec et al., 2013).

Table 6: Summary of academic studies into alternative applications for MSW-IBA.

App	Use	Study details	Conclusion/Limitations	Ref.
MATERIAL RECOVERY (Urban Mining)	Recovery of rare earth elements (REE) and other critical raw materials (CRM)	Based on a full-scale Danish recovery facility, carried out detailed MFA with resource recovery potential of Danish IBA characterised.	REEs were detected in the ashes at conc. 2-3 orders of magnitude lower than typical ore. The lack of REE enrichment with current technology limits options to recover REE's from IBA	Allegrini et al. 2014
		The REE concentration in IBA was determined by ICP-MS following digestion (using a novel method).	REE conc. in IBA indicate prospective low streams. Several methods of prospecting to facilitate urban mining (from IBA) also identified.	Funari et al 2016
		Total elemental composition determined from untreated IBA using XRF and ICP-MS, which informed SFA to determine CRM conc.	IBA considered a low concentration stream of precious and high-tech metals. Conc. of magnesium, copper, antimony and zinc found to be close to that of low grade ore.	Funari et al. 2015
GROWTH SUBSTRATE	Green / Brown roofs	Six-year experiment, testing effects of recycled aggregate type (including IBA) on the development of vegetation on brown roofs.	IBA is not recommended as a brown (biodiversity) roof growth substrate due to its limited capacity to hold moisture, but could have potential for use in extensive Sedum green roofs.	Bates et al. 2015
PYROXENE CERAMICS	Porcelainized stoneware	Glassy frits obtained from MSW-IBA compared against glass cullet as sintering promoters in production process.	Glassy frits improved water absorption and spot resistance, but did not significantly change bending strength. However, tile planarity was adversely affected and colour modified.	Barbieri et al. 2002
		Replaced feldspar and quartz sand with post-treatment IBA in production, and characterised in accordance with ISO rules and leaching potential.	Mechanical characteristics comparable to commercial products, ISO classification achievable and additional environmental benefits noted.	Schabbach et al. 2012
ALKALI ACTIVATED CEMENTS	Hybrid cements	Compared Hybrid cements made from IBA, Portland cement and commercial cement wrt. leaching potential, mechanical strength, and characterisation of reactions produced.	Acceptable mechanical strength and reaction similar to Portland cements. Alkali activation of hybrid cement lowered leaching potential. Raised conc. of chloride ions in hybrid cement not suitable in manufacture of structural concrete.	Garcia-Lodeiro et al. 2016
	Geopolymers	IBA was used to replace a proportion of metakaolin within geopolymers, with chemical, elemental and loss on ignition analysis completed.	IBA has been demonstrated as suitable source materials for producing metakaolin-blended geopolymers.	Lancellotti et al. 2013
		IBA is used as sole source material for geopolymers cured for different lengths of time. Basic structural information was gathered for each curing time.	Geo-polymeric networks were produced without the need for metakaolin. However, due to metallic content, a porous morphology, comparable to other lightweight materials, was noted.	Lancellotti et al. 2015
AERATION AGENT	Aerated concrete	Aluminium and silica from IBA used as aerating agent in production of autoclaved aerated concrete (AAC). Characteristics compared against standard.	IBA-AACs successfully synthesized by using IBA as aerating agent. Had a higher density, compressive strength and shrinkage when compared against standard, attributing to increased porosity and water loss during drying processes.	Song et al. 2015
HYDROGEN GAS PRODUCTION	Use of Aluminium species to generate Hydrogen	Identification and characterisation of metallic aluminium and aluminium alloys contained within IBA potential to aid hydrogen gas generation assessed.	Production of hydrogen from IBA ranged between 8.4 and 35.3 l/kg of dry ash, metallic aluminium aggregates converted to gel-like and crystalline Al-rich hydrate phases. Inherent alkalinity of IBA noted as key parameter in hydrogen generation reactions.	Saffarzadeh et al. 2016
		Evaluated the recovery of metallic aluminium, through metal recovery and in generation of hydrogen gas for use as a clean fuel.	Hydrogen gas was successfully produced, and performed better, in terms of overall energy balance, than the metal recovery. Economic investment required to use the metallic aluminium to generate hydrogen when compared against metal recovery was found to be unjustifiable.	Biganzoli et al. 2013
PURIFICATION AGENT	Landfill gas purification before energetic valorisation	Pilot plant study, assessed qualities of IBA to remove hydrogen sulphide, methyl mercaptan and dimethyl sulphide from landfill gas.	IBA successful in sequestering hydrogen sulphide and methyl mercaptan through acid-base reactions. While dimethyl sulphide was retained by physical adsorption. Poor retention of methane means the energetic content of landfill gas will not be lowered.	Ducom et al. 2009
	Mesoporous silica materials	Mesoporous silica materials were synthesised from IBA, and effectiveness in removing heavy metals from aqueous solutions was assessed.	Mesoporous silica materials were successfully synthesized from IBA and were shown to have potential for use as adsorbents for the removal of heavy metals from aqueous solutions.	Liu et al. 2014

In addition to incineration, EU member states have increasingly employed the use of advanced material sorting such as MBT to meet landfill diversion targets. This increasing prominence of MBT has seen a change in the nature of wastes sent to landfill, with an increasing contribution from 'fines' (the small fragments that remain after processing via mechanical treatment such as trommel screens, HMRC, 2016a). As the composition of fines is highly variable, being dependent on both the composition of the input waste and the separation techniques employed (Dias et al., 2012), this change in the nature of landfilled waste has given rise to a key question regarding the classification of fines as either active or inactive.

UK policy has attempted to address this question with the publication of orders sanctioned by the UK LFT. As fines are often processed from a mixed waste and therefore contain a mixture of materials, even those arising from waste streams dominated by inert materials (e.g. C&D waste) may not consist of qualifying materials (listed as inert in the QMO) in their entirety (Balch, 2014). While the QMO does make allowance for the presence of a 'small' amount of active waste, known as 'incidentals', what constitutes a small amount is not clearly defined. Indeed, only generic guidance is provided, that "whether an amount of standard-rated waste [i.e. active waste that is liable for the standard tax rate] is small will depend on the circumstances and is a matter of fact and degree. As a guide, the dictionary definition of small is "either small in size or weight, or insignificant or unimportant" (HMRC, 2016a). Thus, in the absence of a clear definition, what emerged in practice was a relatively informal system, where the responsibility of determining whether an amount of incidental material qualified as small rested with the landfill operator (HMRC, 2016a). As such, the classification of fines has been strongly debated within the waste industry, with concerns that the lower rate of tax was not being applied equitably and that more clarity was required concerning liability (Balch, 2014; Goulding, 2015a, b).

To address these concerns, the waste industry was consulted on proposed secondary legislation to use a standardised Loss On Ignition (LOI) test to classify fines where an LOI of 10% or less would indicate inert material with a 'small' amount of contamination (HMRC, 2014a). Overall, respondents agreed with the proposal, but raised concerns regarding conformity of fines to the QMO, time required for businesses to adjust, the 10% LOI limit, and operational aspects of the LOI test (HMRC, 2014b). A number of revisions were made in response, including a prescribed LOI testing regime, and the Landfill Tax (Qualifying Fines) Order

2015 (QFO) was introduced where responsibility and liability for implementation was placed primarily with the landfill operator, but where correct classification of fines was also dependent on information provided by the waste processor. Figure 12 presents a synopsis of the process as implemented, highlighting pre-acceptance checks, determination of risk categories and the prescribed LOI test.

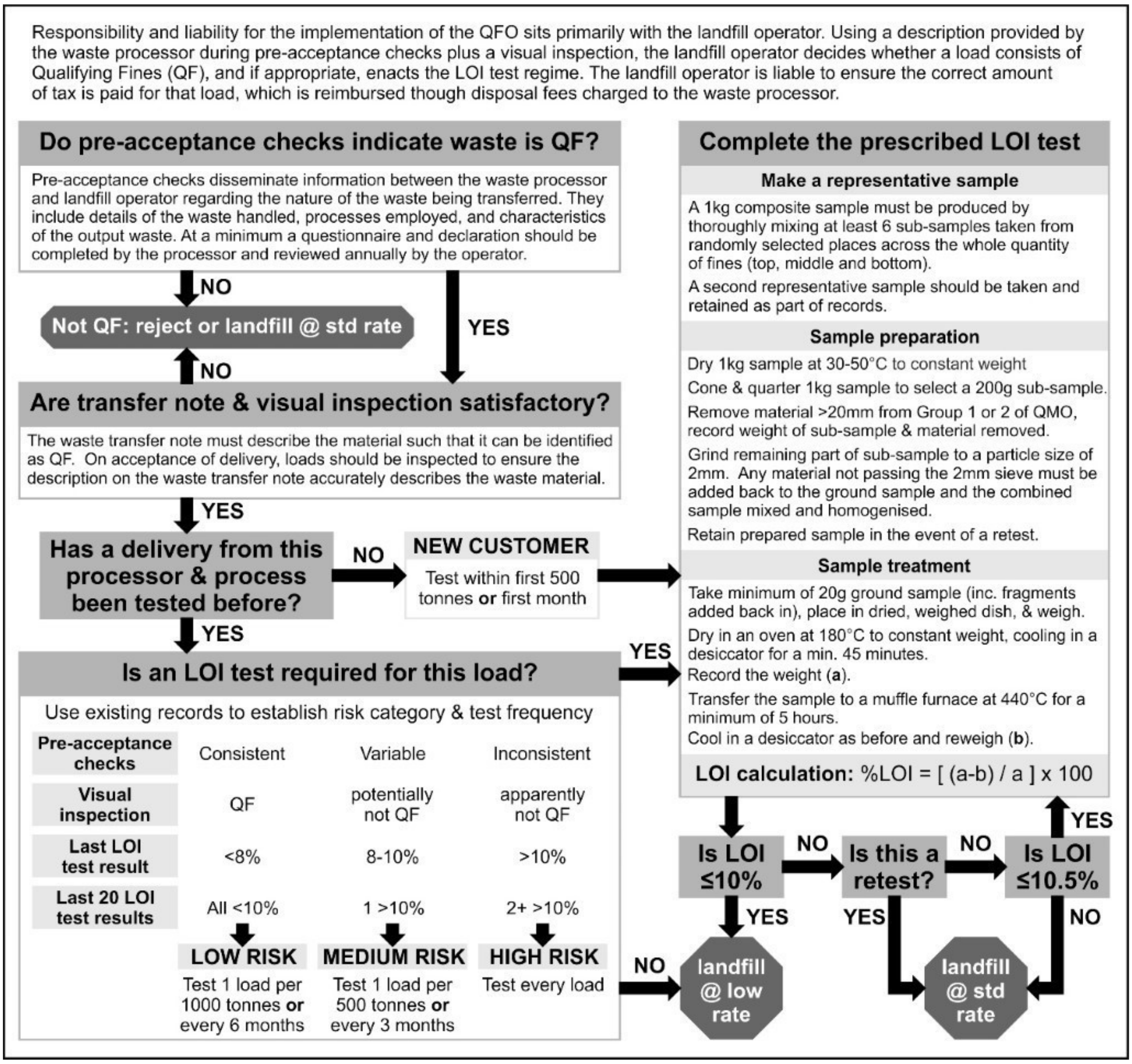


Figure 12: The process for determining the appropriate landfill tax rate for residual fines in accordance with the Landfill Tax (Qualifying Fines) Order 2015. Based on the guidance provided by HMRC (2016a).

While the QFO provided a degree of clarity on the classification of fines, debate continued regarding the economic and practical realities of implementation (Balch, 2014; Coll, 2015). The QFO has seen some materials that may have qualified as inert (based on the QMO and the interpretation of a ‘small’ amount of incidentals) now classed as active waste unless proven otherwise, creating uncertainty and scepticism amongst operators (Balch, 2014; Coll, 2015). Furthermore, while the QFO has encouraged further material recovery in some cases (e.g. removal of metal fragments from C&D derived fines to reduce the total weight of fines sent to landfill), it has been suggested that in other cases it may reduce the financial viability of recycling operations, thereby acting contrary to the intended incentive (Coll, 2015).

These issues are further compounded by concerns regarding the reliability of the LOI test regime (Goulding, 2016, 2015a, b). While the prescribed sampling method attempts to homogenise loads, Goulding (2015a, b) has provided anecdotal evidence that it can be manipulated. Similarly, Goulding (2016, 2015a) cites concerns raised by test providers regarding differing interpretation of the LOI test method and the consistency of data produced.

While currently limited to grey literature sources (such as industry reports and magazine / newspaper articles), this highlights the risk of unintended consequences when developing effective environmental policy and the role of stakeholders in enabling its success. Indeed, it is important to engage with stakeholders not only when developing environmental policy (i.e. within consultation phases) but also during implementation. As such, lessons can be learnt from the implementation, and limitations, of existing waste and resource management policy when developing environmental policy in anticipation for, and in the transition to, the circular economy.

2.5.8 Going forward, what are the limitations of EU waste and resource management policy?

While the EU can be said to be advanced where waste and resource management policy is concerned, in addition to dealing with residual wastes, there are a number of limitations (evident in existing waste and resource management policy) that need to be overcome to facilitate the transition to the circular economy. Limitations include poor levels of stakeholder engagement, un-coordinated use of measures and instruments, technological lock-in and the continued focus on end-of-pipe solutions.

It has been noted that consumers, i.e. those that buy and dispose of products, play an important role in waste management, particularly with respect to material recovery (Triguero et al., 2016; Bulkeley and Gregson, 2009), where participation in a waste management strategy strongly impacts its success (Babaei et al., 2015). However, lack of public awareness and participation has been shown to limit implementation and thereby the success of current waste management strategies (Babaei et al., 2015). This has been exacerbated by the household being placed as the end-of-pipe delivery and / or collection point of materials within the waste management system, where this system fails to acknowledge the many outside (of the immediate waste-policy realm) conduits that influence waste generation and therefore collection (Bulkeley and Gregson, 2009). Indeed, Bulkeley and Gregson (2009) argue that households remain a closed entity within the waste management system where the generation, storage and circulation of unwanted materials (practices that are closely linked to consumption, identity and values) are largely hidden, and therefore not incorporated into waste and resource management policy.

With respect to measures and instruments, progressive waste and resource management strategies have routinely used financial incentives, with different levels of sanction applied in combination with the waste hierarchy. While fiscal instruments such as landfill taxes have been successful in diverting waste from landfill, to what extent they promote material recovery is less clear. The financial competitiveness of secondary materials can be enhanced through taxation on competing virgin materials or on waste disposal, where Solderholm (2011) argues that the latter can be more effective due to low administration costs and increased policy acceptance. However, Martin and Scott (2003) found that while the landfill tax had increased landfill diversion in the UK, it had been less successful in promoting the top waste hierarchy priorities (such as recycling and reuse). Likewise, in an EU-wide study, Mazzanti and Zoboli (2008) concluded that while landfill taxes can lead to the management of waste being promoted up the waste hierarchy (to recovery or recycling), they do not create a backwards incentive to reduce waste generation.

While full implementation of the waste hierarchy would align with the circular economy, it has been argued that too little emphasis is placed within waste and resource management policy on higher priority R-imperatives. For example, Mazzanti and Zoboli (2009) and Fischer (2011) have noted the absence of quantitative targets for reduction or reuse, which could create a perceived policy bias towards recycling and disposal. As such, Kirchherr et al. (2017) argues that the concept of the circular economy could be subverted and thereby implementation limited if the waste hierarchy does not explicitly identify (and implement) waste prevention imperatives as the highest priority.

To address this issue, researchers have called for a re-framing of the waste hierarchy in terms of resource use and productivity, arguing that this would help policy makers ensure that they not only disincentivise disposal, but also adequately incentivise preferred environmental options (Gharfalkar et al., 2015; Van Ewijk and Stegemann, 2014). However, care must be taken to apply the correct amount of sanction, where under-regulation may lead to the careless handling of wastes. Conversely, over-regulation, regulation that is unclear, or an absence of compensatory incentives, may hinder the re-use of waste materials by creating excessive bureaucracy and stifling innovation (Gharfalkar et al., 2015; Jaffe et al., 2005).

Perhaps the most significant limitation of waste and resource management, particularly with regards to the circular economy, is that for the main part it is still only considered as an ‘end-of-pipe’ solution (Ghisellini et al., 2016; Silva et al., 2017). However, it is argued that instead the waste and resource management sector should be recognised as an underutilised ‘resource industry’ (with the means to recover resources and reduce environmental impacts), with appropriate policies and management schemes to reflect this.

This is further undermined by disparity of waste policy and management systems across nations. Schroeder et al. (2018) argues that the circular economy can help developing nations ‘leap-frog’ the developmental pathway carved out by developed nations and thus create development pathways that are more sustainable. However, to do this, developing nations must overcome the continuation of existing corporation structures, the continued dominance of dis-integrated production systems and growing inequalities (Schroeder et al., 2018). Furthermore, poor socio-economic conditions within developing nations such as rapid population growth, rural-to-urban migration and low-skilled cheap labour, have led to waste management strategies that lack facilities, suffer from insufficient service coverage and use improper disposal methods (Mukhtar et al., 2018). Indeed, effective waste management remains a challenge for some developing countries where practices such as disposal in unregulated dumps and open burning are the norm, and so the development of sanitary (rather than progressive or towards the circular economy) waste management is prioritised

(Mukhtar et al., 2016; World Bank, 2018). In a broader context, this highlights the need of waste and resource management to reflect local societal, administrative and economic conditions, where emphasis is placed on aspects which are deemed important to the local community (Mukhtar et al., 2018).

These limitations to the implementation of the circular economy highlight **the need to understand the role of waste and resource management in the transition to the circular economy.** Where, **efforts should be made to identify ways in which to future-proof the sector** so that it can overcome barriers and fulfil its contribution to the circular economy.

2.6 Summary of the reviewed literature.

Current patterns of consumption (based on the linear economy) have been shown to be environmentally and economically unsustainable. Here, the reliance on the coupling of growth and resource use, has led to significant environmental damage (including climate change), severe resource depletion, and rising geopolitical tensions. These issues are fuelled by a growing global population and increasing consumer affluence. To address these issues, the transition to the circular economy has been recommended as an alternative. The circular economy decouples economic growth from resource use, and simultaneously meets the sustainable development objectives of economic growth, social progress, and environmental protection.

While there is widespread acknowledgement for the need to transition to the circular economy, a standardised definition, and the steps required in the transition, are still subject to debate and interpretation. To rise above this level of debate, this study instead, unpicked the concept of the circular economy by identifying the aims, core concepts and principles, and enablers, all of which should be considered during implementation. Also highlighted, is the importance of stakeholder engagement, where all sectors of the economy, government and public are equally responsible for ensuring successful implementation.

While the circular economy has been acknowledged internationally, several barriers have impeded implementation. These include; financial barriers (such as initial investment and ongoing viability), structural barriers (such as unstandardized systems, poor information availability, and the isolation of sectors), operational barriers (such as poor infrastructure, restricted markets, and complicated policy and regulation regimes), attitudinal barriers (such as the tendency for stakeholders to avoid risk, poor consumer behaviour, and entrenched institutional conventions), and finally, technological barriers (such as poor design, limited integration, and untested materials). Thus, in the transition to the circular economy, mechanisms should try to avoid or overcome these barriers.

It has been suggested that some of these barriers can be attributed to the poor quantification and management of material and waste flows, which can be addressed through effective waste policy. Here, the contribution of waste management and policy to the transition to the circular economy has been highlighted. Specifically, this can be evidenced by the similarities to the existing zero-waste concept, adoption of the CEP within EU waste policy, and the effective use of the waste hierarchy to encourage resource efficiency.

However, for waste and resource management policy to be effective, and thereby contribute to the transition to the circular economy, it must overcome existing limitations and barriers. Mirroring broader barriers to the circular economy, waste management policy is limited by poor levels of stakeholder engagement, un-coordinated use of measures and instruments, and a continued focus on end-of-pipe solutions. These limitations are further undermined by the disparity in waste and resource management systems across different nations. Indeed, while some (wealthy) nations have employed effective integrated waste and resource management systems, which encourage resource efficiency, for others, progressive waste management remains a challenge. Here, the introduction of sanitary waste management remains the priority.

The challenge for waste management is thus; how to contribute positively to the transition to the circular economy in the future, while continuing to improve sanitary waste management in the present. While effective waste policy has a key role to play in addressing this challenge, limitations of existing policy may be acting as a barrier. Therefore, the overarching aim of this research is to;

Identify and address potential limitations within EU and UK waste policy that may be acting as barriers in the transition to the circular economy.

Concerning current waste policy, three key areas were identified by the literature review that warrant particular scrutiny. The first regards the existing level of adoption of EU waste policy by member-states, specifically in light of circular economy principles. The second key area concerns the management of residual wastes, particularly with respect to evolving EU targets and objectives. Finally, the third area requiring scrutiny concerns the future, specifically how well-equipped current waste policy is to enable the transition to the circular economy.

To achieve the overarching aim of this research, the following objectives and associated research questions (RQ) were addressed:

OBJECTIVE 1: Critically evaluate the alignment of waste and resource management policy with the principles of the circular economy.

A key characteristic of UK environmental policy sees objectives set by the EU (i.e. at a supranational level), whereas implementation strategies are developed by the four devolved nations. So far, comparisons between the four devolved nations have been limited, with little or no consideration of the extent to which they are aligned with circular economy principles. Here, a systematic comparison of these policies not only allows for a critical evaluation of the individual documents, but also enables examples of good and bad practice to be identified. To address this objective, the following research questions were considered:

> **RQ1:** When compared, how do the four devolved nations (England, Scotland, Wales and Northern Ireland) adopt EU policy within their waste management strategies, and how well does this align with circular economy principles?
>
> **RQ2:** What examples of good and bad practice are present in the waste and resource management strategies of the four devolved nations (England, Scotland, Wales and Northern Ireland)?

OBJECTIVE 2: Identify and develop solutions for limitations of existing waste and resource management policy, with a specific focus on the management of residual waste materials.

While it is acknowledged that existing waste policy has improved greatly over the past two decades, further improvements will require the consideration of residual wastes. This study has identified two residual wastes of particular prominence, MSW-IBA and MBT-Fines. Under the current policy regime, these residual wastes will become more prominent. To date, the management of these residual wastes have received little to no consideration within the academic literature, particularly in light of evolving EU and national policy. To address this gap in the knowledge, the following research questions were considered:

RQ3: What impact could increasingly stringent EU policy targets have on the production, management and utilisation of MSW-IBA?

RQ4: Can the use of an ineffective instrument to characterise MBT-Fines have unintended consequences on overarching policy objectives?

OBJECTIVE 3: Considering the limitations of waste policy, along with examples of good and bad practice, apply and explore the concept of readiness, specifically in the transition to the circular economy.

Within the literature, the key role of the waste management sector in the transition to the circular economy has been widely acknowledged. However, efforts must now be made to understand that role, and to future-proof the sector against any potential barriers. Drawing an analogy with the energy sector, this research explores the concept of readiness, and its potential application to the waste management sector. To address this objective, the following research questions were considered:

RQ5: What recommendations can be made to overcome potential barriers to the circular economy within existing waste policy?

RQ6: Can the concept of “readiness” be used by the waste and resource management sector to aid the transition to the circular economy?

CHAPTER 3: Methods

This chapter presents the methodological approach used in this study to address the research aims and corresponding research questions.

3.1 Chapter introduction and outline

To justify the use of the pragmatism paradigm within this research, a brief review of common philosophical paradigms is first presented. Followed by how philosophical paradigms inform methodological approaches and the approaches used within this research. The four methodological stages employed within this research are then detailed, followed by the steps taken to adhere to ethical approval requirements.

3.2 Choice of philosophical paradigm

3.2.1 What is a philosophical paradigm?

There are varying views, both across and within disciplines, concerning the development of knowledge (what is it, how is it generated, etc.). Philosophical paradigms provide the assumptions that underpin and aid decision making with regards to research, what informs it and how it is carried out (Guba, 1990). When defining philosophical paradigms, differences can be seen in the literature.

For example, Wahyuni (2012) describes a philosophical paradigm as a thinking framework;

> *"A set of fundamental assumptions and beliefs as to how the world is perceived which then serves as a thinking framework that guides the behaviour of the researcher".*

Whereas, Shannon-Baker (2015) simply defines a philosophical paradigm as;

> *"A system of beliefs and practices that influence how researchers select both the questions they study and methods that they use to study them".*

These definitions describe a researcher's 'worldview', where a position concerning what constitutes reality, based on their own perceptions, informs how data is collected and interpreted (Kivunja and Kuyini, 2017; Scotland, 2012). In contrast, other definitions make explicit reference to disciplinary expectations and / or norms. For example, Creswell (2009) describes a philosophical paradigm as;

"A basic set of beliefs that guide actions, aka paradigms, epistemologies and ontologies. Shaped by the discipline area, beliefs and past research experiences".

While, Biddle and Schafft (2014) define a philosophical paradigm, based on Kuhnian theory, as;

"Collections of disciplinary assumptions and norms that scientists working in a field share. They therefore constitute a set of professional commitments and agreed-upon understandings and assumption regarding questions that can be legitimately posed within a field of inquiry, and the methods most appropriate for addressing those questions".

While these definitions differ in terminology, they all describe philosophical paradigms as the school of thought or a set of shared beliefs that researchers use to inform studies. Indeed, the importance of philosophical paradigms is that they provide the beliefs and diktats that influence what should be studied, how it should be studied and how results should be interpreted (Kivunja and Kuyini, 2017).

Philosophical paradigms are described by four aspects; ontology, epistemology, axiology and methodology (Biddle and Schafft, 2014; Kivunja and Kuyini, 2017).

Ontology is the philosophical study of the nature of reality providing the basic categories of things that exist and their relations (Biddle and Schafft, 2014; Kivunja and Kuyini, 2017). It concerns how the researcher comprehends reality and the assumptions that are made to believe something makes sense or is real (Kivunja and Kuyini, 2017).

Epistemology concerns the relationship between the researcher and what is known (Biddle and Schafft, 2014). It describes how knowledge is created, acquired and communicated and so what counts as knowledge within the world (Kivunja and Kuyini, 2017; Scotland, 2012).

Axiology concerns the values and ethics that need to be considered during research development (Biddle and Schafft, 2014). It defines and evaluates the concepts of right and wrong within the research parameters and considers approaches based on these values (Kivunja and Kuyini, 2017).

The final aspect, methodology, concerns the rationale for choosing the tools used for interrogation (Biddle and Schafft, 2014). It is a broad term that refers to the research design, methods, approaches and / or procedures used within a study to achieve research objectives (Kivunja and Kuyini, 2017).

3.2.2 What types of philosophical paradigms are there?

Different researchers have identified a range of paradigms, all based on their own assumptions that inherently contain differing ontological, epistemological and axiological views (Scotland, 2012). Traditionally, researchers fell into two camps; positivists and interpretivists, aligning with paradigms that generally favour opposite ontological, epistemological and axiological views. Purists of positivism and interpretivism view their paradigm as 'ideal' for research and based on their discrete assumptions of reality and knowledge, disagree with the mixing of viewpoints and associated methodologies (Burke Johnson and Onwuegbuzie, 2004). Given that underlying assumptions are often based on conjecture, the argument not to mix viewpoints and methodologies has since been dispelled (Scotland, 2012). Indeed, philosophical paradigms have now expanded to include a wide range, with Teddlie and Tashakkori (2009) suggesting an infinite number of paradigms that no longer conform to discrete assumptions and includes mixtures of viewpoints and methodologies (Figure 13).

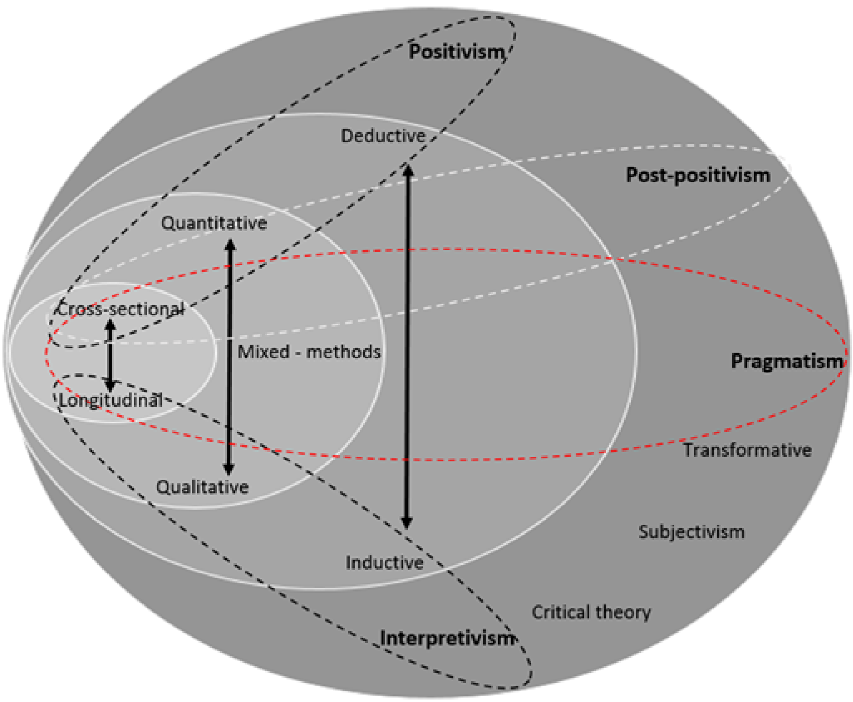


Figure 13: Range of philosophical paradigms with methodological viewpoints (based on the 'research onion'; Saunders et al., 2007).

Figure 13 and Table 7 introduce four commonly identified paradigms that employ different methodological approaches, which reflect the differing assumptions regarding the nature of reality (ontology) and knowledge (epistemology) and the role of values in research (axiology). Paradigms include positivism and interpretivism at the extremes, pragmatism in the middle ground, and post-positivism positioned between positivism and pragmatism.

Table 7: Assumptions made concerning ontological, epistemological, axiological and methodological viewpoints for a range of philosophical paradigms.

	Positivism	Post-Positivism	Pragmatism	Interpretivism
Ontology	**Realism**	**Critical realism**	**Dependant on RQ**	**Relativism**
Epistemology	Objectivism	Modified dualism	Dependant on RQ	Subjectivism
Axiology	**Value-free, Etic**	**Value-laden, Etic**	**Values important in interpretation, Etic-emic**	**Value-bound, Emic**
Methodology	Deductive, Quantitative	Primarily deductive Quan or Qual	Deductive / Inductive Quan, Qual or Mixed	Inductive, Qualitative

Positivism and interpretivism occupy the extremes of the philosophical paradigm scale. Regarding their ontological positions, the former takes a realist view that is external and objective, whereby the object being studied has an existence independent of the researcher and reality is not mediated by the senses or constructed by individual perceptions (Scotland, 2012; Wahyuni, 2012). In comparison, interpretivism takes a relativist view that is subjective, whereby reality is constructed by individuals (Scotland, 2012). It acknowledges that individuals with varied backgrounds, assumptions and experiences can contribute to the on-going construction of reality (Wahyuni, 2012).

With respect to epistemology, positivism adopts an objective view point, whereas interpretivism is subjective. Objectivism assumes absolute knowledge is gained impartially, the researched and the researcher are independent entities and meaning resides solely in objects (Scotland, 2012). The scientific approach is an example where numeric measures are used to generate acceptable knowledge (Wahyuni, 2012). In contrast, subjectivism is based on real-world phenomena, where different actors may construct meaning differently but consensus is achieved (Scotland, 2012). This allows for the inclusion of a broader social context through social interaction, and for knowledge to be culturally derived and historically situated (Scott, 2012; Wahyuni, 2012).

Due to positivism taking an objective viewpoint, it can be said to follow an Etic axiology, whereby the study is observed from outside of the system (Olive, 2014). This follows a value-free axiological viewpoint that assumes independence between the researcher and the data (Kivunja and Kuyini, 2017). In contrast, interpretivism, being subjective, follows an Emic axiology whereby the study is observed from inside the system (Olive, 2014). This follows a value-bound axiological viewpoint that assumes that the values of the researcher will be reflected in the outcomes, where a balanced report of the findings is sought (Kivunja and Kuyini, 2017).

Regarding methodological approaches, positivism is directed at explaining relationships by taking a deductive approach, while interpretivism is directed towards understanding phenomenon from an individual’s perspective or investigating interaction among individuals using an inductive approach (Scotland, 2012). Positivism requires verifiable evidence sought via direct experience or observation, preferably through true-experiments. This is achieved through quantitative methods that require empirical testing, randomised sampling and controlled variables (Scotland, 2012). In contrast, interpretivism tends to use qualitative methods such as case-studies (in-depth studies of events or processes), phenomenology (study of direct experience), hermeneutics (deriving meaning from language) and ethnography (study of cultural groups) (Scotland, 2012).

Moving away from an extreme position, post-positivism can be thought of as an extension to the positivism paradigm, where it maintains an objective viewpoint but allows interpretation through social conditions. This is achieved by using observable phenomena to provide credible data, but creating an additional focus based on the context or contexts in which the phenomena was observed. Here, the research is Etic, but value-laden where the researcher can be biased by world views and cultural experiences, and methods can be either quantitative or qualitative (Wahyuni, 2012).

Pragmatism occupies the middle ground and has grown in popularity due to its flexibility and utility (Biddle and Schafft, 2014). As it is outcome orientated, it is characterised by an emphasis on communication and shared meaning-making, which are applied to create practical solutions to social problems (Shannon-Baker, 2012). As such, ontological and epistemological assumptions depend on the research question being studied. This allows for the best answer to be found for each specific research question, and a focus on practically applied research that integrates different perspectives to interpret the data collected (Wahyuni, 2012). Regarding its axiology, pragmatism takes an Etic-Emic viewpoint that is value-bonded, meaning that values play a vital role in the interpretation of results, with researchers adopting both an objective and subjective point of view (Wahyuni, 2012). As this paradigm is directed by the needs of the research question, research design and methodologies can take multiple forms including; quantitative, qualitative, mixed methods and multi-methods, depending on what the researcher judges effective (Biddle and Schafft, 2014). Here, the researcher must be able to support any knowledge claims produced from the methodologies selected given the data available, possibilities for analysis and resources available (Biddle and Schafft, 2014).

3.3 Impact of paradigm on methodological approach

While methodological approaches are closer to research practice than philosophical concepts, their theoretical and ideological foundations reflect the philosophical paradigm employed (Wahyuni, 2012). Likewise, the choice of research methods (practical application of research including procedures, tools and techniques) is guided by the underlying set of beliefs and assumptions stated by the appropriate methodological approach (Wahyuni, 2012). Here, it is noted that a research method itself is a-theoretical and so is independent from methodologies and paradigms. Therefore, while some methods are generally associated with certain methodological approaches, any individual method can be used within any methodology or paradigm (Wahyuni, 2012).

In general, there are three types of methodological approaches; those that employ quantitative strategies, those that employ qualitative strategies and those that employ mixed methods that include both quantitative and qualitative strategies (Creswell, 2009).

3.3.1 Quantitative methodological strategies

Quantitative strategies align with positivism or post-positivism paradigms, employing pre-determined, instrument-based tools to collect data and perform statistical analysis and interpretation (Creswell, 2009). These strategies include surveys (numeric description of trends and attitudes solicited from a sample of a population) and experimental methods (determining whether a specific treatment influences an outcome) (Creswell, 2009). As shown in Table 8, advantages of using quantitative strategies include control over potential bias, efficient data analysis, examination of probable cause and effect, and drawing conclusions from large populations (Creswell, 2015). However, such strategies have been criticised for being impersonal, providing limited understanding particularly with respect to context and being largely driven by the researcher (Creswell, 2015).

Table 8: Advantages and disadvantages of Qualitative and Quantitative methods (after Creswell, 2015).

Method	Advantages	Disadvantages
Qualitative	**Detailed perspectives**	**Limited generalisability**
	Captures voice of participants	**Provides only soft data**
	Experiences understood in context	**Studies few people**
	Based on participant views	**Highly subjective**
	Appeals to enjoyment of stories	**Minimal use of researcher expertise**
Quantitative	Draws conclusions from large populations	Impersonal
	Analyses data efficiently	Does not record words of participants
	Investigates relationships within data	Provides limited understanding of context
	Examines probable causes and effects	Largely driven by researcher
	Controls bias	
	Preference for numbers	

3.3.2 Qualitative methodological strategies

In contrast, qualitative strategies tend to align with the interpretivism paradigm, where emerging methods (where methods evolve in context with findings), ethnographic design and observation of behaviour feature (Creswell, 2009). Qualitative strategies can take five different forms; ethnography (cultural groups are studied within their natural setting over a prolonged period), grounded theory (grounded in the views of the participants, data is constantly compared with emerging categories), case studies (an event, process or individual is explored in depth, bound by time), phenomenological (experience, as described by the participants, of an event) and narrative (participants provide stories of their lives for chronological analysis) (Creswell, 2009). As detailed in Table 8, advantages of qualitative strategies are focused on their ability to provide detailed perspectives and the understanding of experiences in context. However, disadvantages include its limited generalisability, highly subjective nature and reliance on participants (Creswell, 2015).

3.3.3 Mixed methods strategies

While quantitative and qualitative strategies take different stances in the collection, analysis and interpretation of data, both follow the general process of research, which is to identify a problem, determine relevant research questions, collect and analyse data, and to interpret results (Creswell, 2015). This allows for the third type of methodological approach, mixed methods. Mixed methods collect multiple forms of data based on both quantitative and qualitative methods, which can be pre-determined and /or emerging. The data collected can draw on all possibilities and eventualities, can be analysed using statistical and non-statistical methods, and interpretation can be made across and between different data sets (Creswell, 2009). Mixed methods assume that the combination of statistical trends (quantitative data) along with personal experience (qualitative data) allows for a better understanding of the research problem, due to the collective strengths of the two data types (Creswell, 2015).

While “purist” quantitative (QUAN) and qualitative (QUAL) methodologies have distinct characteristics, within mixed methods strategies a continuum of methodological approaches is presented (as illustrated by Figure 14; Teddlie and Tashakkori, 2009). Here, the approach is based on the orientation of the method, i.e. either towards quantitative or qualitative methodologies, and the integration of different methods used, i.e. how the quantitative and qualitative methodologies are combined. Mixed methods that place equal weighting on quantitative and qualitative approaches, and thus achieve complete integration, are termed QUAN-QUAL methods. Similarly, those that are primarily orientated towards quantitative methods but integrate some qualitative approaches, are termed QUAN-qual methods. Likewise, those that are primarily oriented towards qualitative methods but employ some quantitative approaches are termed QUAL-quan methods.

Figure 14: Continuum of methodological approaches (adapted from Teddlie and Tashakkori, 2009).

Creswell (2015) has identified seven general types of mixed methods design. The first three are based on a basic design where;

1 both quantitative and qualitative data is collected together and compared to provide an overall conclusion (Convergent),

2 qualitative methods are used to explain quantitative results in more depth (Explanatory sequential), and,

3 quantitative data is collected and analysed, building upon the results of an initial qualitative phase (Exploratory sequential).

When a conceptual or theoretical framework shapes the orientation of the research, an advanced mixed method design is used. Here, basic design (either convergent, explanatory or exploratory);

- is embedded within a larger experimental framework (Intervention),
- addresses the framework at different points, where the framework becomes a general focus of the study (Transformative, not to be confused with the paradigm of the same name), or,
- is conducted within a longitudinal study with multiple stages over time, based on the sustained focus provided by the framework (Multistage evaluation).

Finally, the last mixed method design (Integration) can take several forms, depending on type of design, that merge, explain, build and/or embed quantitative and qualitative strategies (Creswell, 2015).

3.4 Research design

The focus of this research concerns the transition to the circular economy and the contribution of waste and resource management policy. As noted in the literature review, considerable research has been undertaken into the concept of the circular economy (e.g. Merli et al., 2018; Kirchherr et al., 2017; Korhonen et al., 2018), where the interpretivism paradigm has been widely employed. As this study focuses on the implementation of the circular economy (thereby going beyond the concept of the circular economy), and in particular barriers to transition, the inclusion of principles, enablers and stakeholders is necessary. Substantial research has also been conducted within the waste management sector (e.g. Mukhtar et al., 2016; Throne-Holst et al., 2007; Calaf-Forn et al., 2014), and like circular economy-related research has favoured one paradigm, this time positivism. In addition, waste management research has been shown to favour the assessment of single aspects (e.g. Papageorgiou et al., 2009; Parfitt et al., 2001; Bulkeley and Gregson, 2009; Coggins, 2001) within the complex socio-technical system, where consideration of wider context is limited. This research adopts a pragmatist viewpoint that allows the implementation of mixed methods, enabling dominantly qualitative assessment of policy documents, quantitative assessment of practices and enablers, and a mixed method approach to assess stakeholder opinion of implementation and future proofing. Furthermore, the use of the pragmatism paradigm allows for the development of practical solutions (the future proofing of the waste management sector) for social problems (transition to the circular economy).

To collect, analyse and interpret data, overall a transformative mixed methods strategy was used, where a conceptual framework (based on the aims, core concepts and principles, and enablers of the circular economy) has been utilised throughout as a common theoretical lens. Figure 15 presents an overview of the study structure, which includes four stages. The first stage, while predominantly quantitative, reviews UK waste strategies following a basic convergent design, where both quantitative and qualitative data is collected separately, but analysed together to provide conclusions and recommendations. The second stage (predominantly qualitative) explores the use of incineration by EU member-states in light of resource efficiency and risk of lock-in. This follows an exploratory sequential design, where qualitative data is used to explore the problem and build recommendations that are supported by quantitative data. The third stage (predominantly quantitative), gathers expert opinions on the implementation of a regulatory instrument, following an explanatory sequential design where qualitative data was collected and used to elaborate on the quantitative results. The final stage explores the concept of readiness and gathers opinions in a stakeholder workshop following a qualitative design, where qualitative data was used to corroborate findings of the previous three stages.

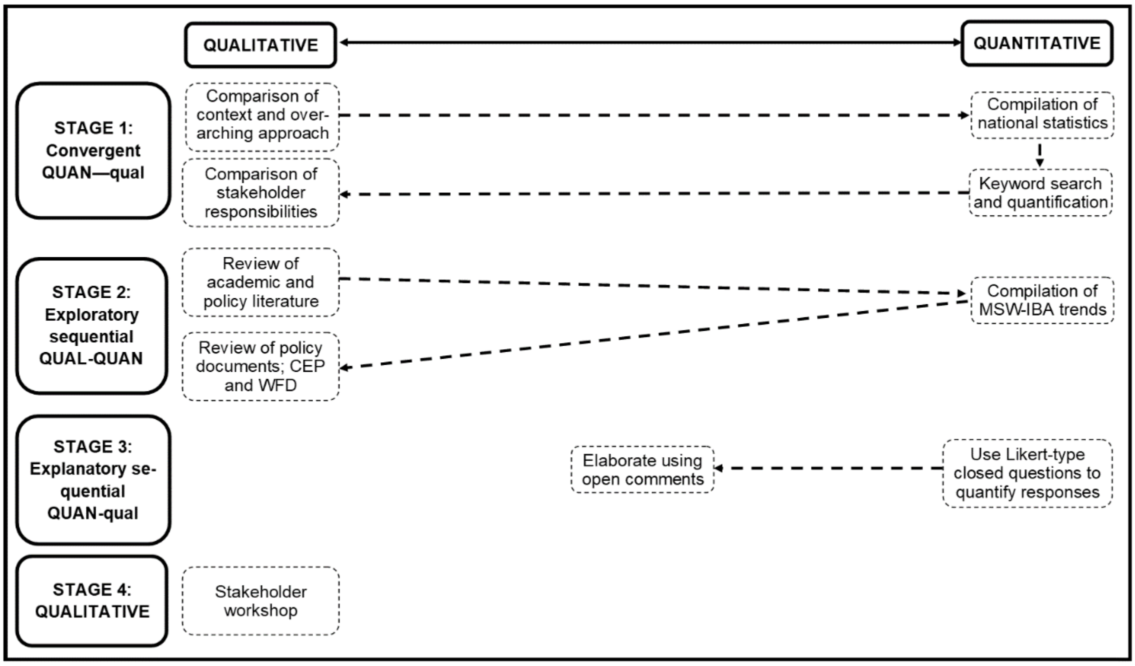


Figure 15: Methodology framework including key approaches and qualitative / quantitative aspects of each stage.

3.4.1 Stage 1: QUAN-qual basic convergent method design to address RQ1 and RQ2.

Stage one addressed RQ1 and RQ2 (Section 2.6, pg. 81) by comparing the alignment of waste management strategies to the circular economy, and thus identifying examples of good and bad practice. In doing so, this stage assessed how well the UK is currently aligned to the circular economy, and what barriers may limit successful implementation of current strategies and the transition to the circular economy.

This stage employed a QUAN-qual method, conducting a content analysis of the waste strategy documents (including both waste management strategies and waste prevention plans) of the home nations of the UK.

Content analysis has been widely employed as both a qualitative and a quantitative method across a range of policy areas, including: health (e.g. Lemiengre et al., 2008), environment (e.g. Maczka et al., 2016), serious crime (e.g. Paoli et al., 2017), procurement (e.g. Testa et al., 2016) and cleaner production (e.g. Peng and Liu, 2016). It provides a simple yet flexible method to describe and quantify phenomena, analyse written, verbal or visual communication, and enhance the understanding of data through the exploration of theoretical ideas (Elo and Kyngäs, 2008). It also allows the inclusion, comparison and corroboration of large volumes of textual data from different sources (Elo and Kyngäs, 2008). To do this and ensure reliability, the inclusion / exclusion of documents should be based on consistent rules and analysis should be objective, systematic and quantitative, whereby categories of analysis are precisely defined (Testa et al., 2016).

Ensuring the application of a consistent inclusion / exclusion criteria, Table 9 presents the documents published by the four home nations of the UK (England, Scotland, Wales and Northern Ireland) that were included within the study. In accordance with EU waste policy, all member states are obligated to publish waste management strategy (WMS) and waste prevention plan (WPP) documents, and at the time of analysis the documents shown in Table 9 were the most recent WMS and WPP documents available for the four home nations. Here, it is noted that rather than publishing separate WMS and WPP documents, Scotland and Northern Ireland (NI) adhere with EU obligations by publishing combined WMS / WPP documents.

Table 9: Waste management strategy (WMS) and Waste Prevention Plans (WPP) published by the four home nations of the UK (England, Scotland, Wales and Northern Ireland).

Document title	Type	Year	Publisher
"Waste Management Plan for England"	WMS	2013	DEFRA, England
"Prevention is better than cure. The role of waste prevention in moving to a more resource efficient economy."	WPP	2013	
"Scotland's Zero Waste Plan"	WMS / WPP	2010	Natural Scotland
"Towards Zero Waste – One Wales: One Planet"	WMS	2010	Welsh Assembly Government (WAG)
"Towards Zero Waste. One Wales: One Planet. The Waste Prevention Programme for Wales."	WPP	2013	
"Delivering Resource Efficiency"	WMS / WPP	2013	Department for the Environment, NI

Figure 16 presents the framework developed for this study, on which the content analysis (predominately a qualitative assessment) is based. The 'circular economy framework' is contains four key aspects of the circular economy, which have been discussed in chapter 2; circular economy aims (Section 2.3.1, pg. 30), circular economy core concepts and principles (Section 2.3.2, pg. 33), enablers of the circular economy (Section 2.3.2, pg. 35) and stakeholder inclusion (Section 2.3.2, pg. 36).

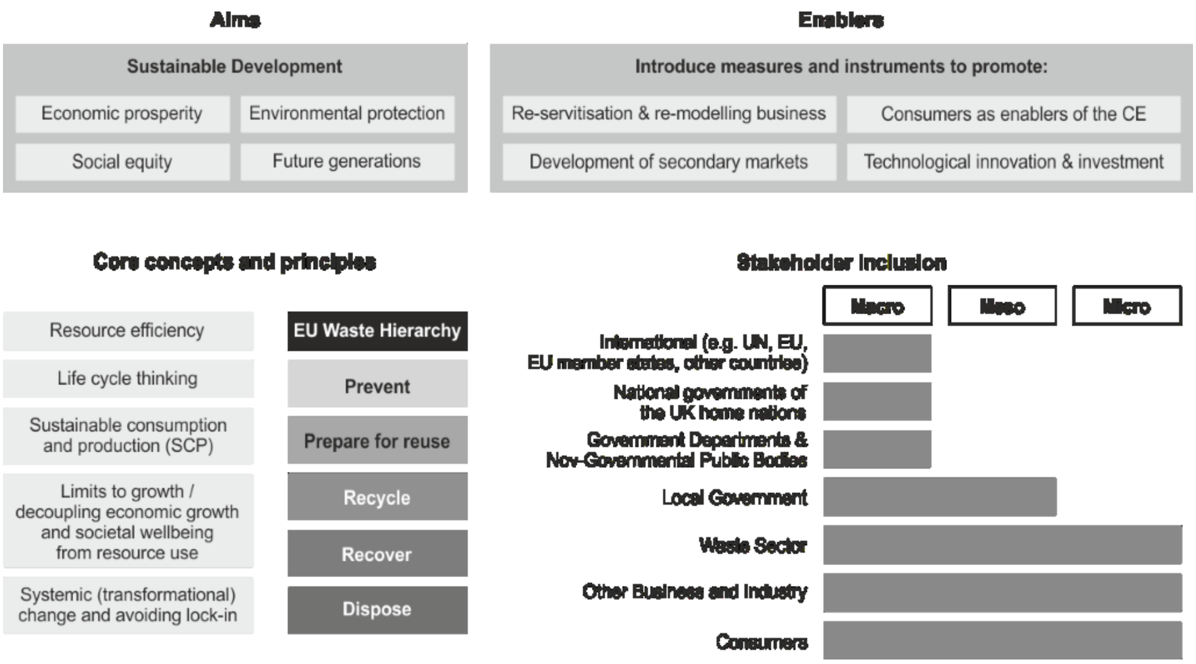


Figure 16: Circular Economy Framework

From the literature, a list of keywords and phrases was compiled for each aspect of the framework (Table 10). This list of keywords and phrases, while primarily identified through the literature review, was expanded during analysis of the documents. Here, keywords and phrases that aligned with an aspect of the circular economy framework were added and searched for within the other documents, thereby achieving comprehensive coverage of aspects associated with the framework across the six documents. An additional focus was placed on the promotion of the waste hierarchy as an operationalisation principle (based on the R-imperatives shown in Figure 8) and the inclusion of stakeholders.

Table 10: Keywords and phrases used to identify inclusion of circular economy framework themes.

Framework themes	Keywords		
Circular economy aims			
Economic prosperity	**Low carbon**	**Circular economy**	**Green economy**
	Decoupling economic growth	**Linear economy (move away)**	**Strong and enterprising economy**
	Zero waste economy	**Sustainable economy**	
Environmental protection	Environmental protection	Climate change	Global warming / GHE
	Greenhouse gas emissions	Reduce carbon/climate impact	Carbon emissons / carbon intensive
	CO2/CO2e emissions	Pollution / Pollutant	Non-ghg/carbon emissions/discharges
Social equality	**Human/public health**	**Social benefits**	**Social well-being**
	Quality of life	**Social justice / fair and just society**	**Equality (of opportunity)**
Future generations	Future WM needs / future waste streams/types (legacy wastes)	Shaping the future / decisions/goals investment etc	Cultural legacy
	Healthy future	Future generations	Sustainable future
Circular economy core concepts and principles			
Resource Efficiency	**Resource use**	**Resource management**	**Resource efficiency**
	Waste as a resource	**Efficient use of resources**	**Use fewer / less**
	Valuing resources	**Replace virgin/raw /primary**	
Life cycle thinking	Lifecycle / lifecycle thinking	Reference to life stages	Cradle to cradle
	Closed loop	Down cycling	Open loop recycling
Sustainable production and consumption	**Sustainable production and consumption**	**SCP**	**SPC**
Limits to growth / decoupling	Decoupling economic growth	Environmental limits / limits to growth	Fair share
Change / avoiding lock in	**Change**	**Transformational change**	**Future proofing / resilient re future needs/demands / ability to upgrade**
	Current legacy wastes (not incl. in future)	**Avoid lock in**	
Circular economy enablers			
Technology Innovation and Invetsment	**Technological progress**	**Innovation**	**Tech.**
	Infrastructure	**Installations**	**Investment**
Business Models	Business models	Supply chains (and supply system)	
Consumers as Enablers	**Behaviour**	**Acceptance / acceptability (public / social) of changes**	**Attitudes**
	Views		
Secondary markets	Market for recyclate	Market development	

Table 10 *continued.*

Framework themes	Keywords Cont.		
Measures and Instruments			
Target and metrics	**Targets** **Ecological footprint**	**Carbon footprint**	**Carbon metric**
Financial	Tax	Incentives	Green procurement
Producer responsibility	**Producer Responsibility**	**Polluter Pays**	
Voluntary agreements	Voluntary agreements	Voluntary standards	
Public engagement	**Education** **Engagement**	**Awareness campaign / programme**	**Communication**
Waste heirarchy			
Reduce	**Prevent** **More with less** **Product service systems** **Products with less haz** **Use recycled materials** **Durable** **Resell**	**Reduce** **Dematerialise / Deweight** **Product design** **Products with less harmful** **Use for longer / longevity** **Pooling** **Second hand**	**Minimise** **Virtualisation** **Products using fewer resources** **Substitute** **Extend life / life extension** **Sharing** **Resale**
Prepare for reuse	Reuse / re-use Replace Restore	Prepare for reuse / re-use Refurbish Remanufacture	Repair Recondition
Recycle	**Repurpose** **Recover**	**Reprocess** **Anaerobic digestion**	**Recycle** **Compost**
Recover	Other / energy recovery Solid recovered fuel / SRF Pyrolysis	Energy from waste Incineration (with energy)	Refuse derived fuel / RDF Gasification
Dispose	**Landfill**	**Dispose**	**Discard**
Mine	Deposit Landfill mining	Incineration (w/o energy) Extraction from landfill	
Stakeholder Inclusion			
International	**Global** **Country name**	**European / EU** **Overseas**	**International** **Member states**
National	Devolved nations England Northern Ireland	United Kingdom / UK Scotland	Government Wales
GD / NGPB	**Agency** **Working / task group**	**Regulator** **Committee**	**Specific departments**
Regional	Authority Region	Local Municipal	Council
Waste sector	**Operator**	**Waste**	**Company names**
Industry / Business	Business Sector Producer Retail	Company Organisation Enterprise Manufacturer	Industry Commercial Private
Consumers	**Consumer** **Residents** **Public**	**Individual** **Schools**	**People** **Home**

The content analysis was completed in two steps. The first step identified the overarching objectives and focus of each document, and collated related statistics. The second step applied the circular economy framework. It is noted that only main body text was analysed with all other text (e.g. cover page material, legends, footnotes, etc.) excluded.

Step 1: The use of circular economy or zero-waste terminology, the broader context within which waste management was positioned, and the overarching approach of each strategy document was noted and compared. This was supported by the compilation of national statistics for 2016 (most current year) and year of strategy publication (2010: Scotland and Wales; 2013: England and NI) regarding population and rates of waste generation, recycling and landfilling (based on DEFRA, 2017).

Step 2: Using a basic automated keyword search, and manual analysis to ensure complete coverage, the inclusion of the keywords and phrases (as shown in Table 10) was evaluated for each document, along with waste hierarchy R-imperatives and stakeholder inclusion (Welsh, 2002). All terms were quantified on a total document and per paragraph basis, with documents ranked (based on per paragraph counts) to compare incorporation of waste hierarchy R-imperatives and stakeholder engagement. Additionally, the responsibilities of each stakeholder group were noted and compared.

3.4.2 Stage 2: Qual-Quan basic exploratory sequential design method to address RQ3.

Stage 2 employs a basic exploratory sequential design method, which is equally qualitative and quantitative, to address RQ3 (Section 2.6, pg. 81) by highlighting an example where the implementation of current waste management policy may have repercussions for implementation of future amendments. This stage used a desktop study, to examine the utilisation of a residual waste, MSW-IBA, in the context of waste policy and future generation trends.

A desktop study, or secondary research, is where existing research is collated and synthesised to address a primary research question. Johnston (2014) argues that the utilisation of existing research in such a way has become more prevalent in research due to technological advances, which have increased data collection, storage and accessibility. While a viable empirical method that requires a systematic method (including procedural and evaluative steps), Johnston (2014) also argues that secondary analysis can be flexible, time/resource efficient and utilised in several ways.

This study centres around the generation, management and utilisation of MSW-IBA. In the context of the circular economy and maximising resource utility, the use of incineration by EU member-states is first explored, noting risks of technological lock-in and resource efficiency. Having noted the increasing prominence of incineration, maximising the use of residual materials that are generated through this waste management option is then assessed, taking note of changing legislation and cross-sector collaboration. To do this, following questions were posed;

1 How has the generation and treatment of MSW changed in the EU over the past twenty years?

2 What are the current, and future, trends in the use of incineration as a waste management strategy?

3 What are the current routes to utilisation for MSW-IBA (use as a waste material vs. use as a non-waste material after EoW classification)?

Secondary sources, a mixture of academic, grey and governmental publications, were used to complete this desktop study; in addition, data sets summarised in Table 11 were used to calculate current and future MSW-IBA generation and utilisation.

Table 11: Source and relevance of data used within a desktop study.

Source	Relevance
Confederation of European Waste-to-Energy Plants (CEWEP)	Publication of country reports (Denmark, France, Germany, The Netherlands, Italy, Portugal, Spain, Austria, Poland, Finland, Czech Republic, Hungary, Ireland, Estonia, Slovakia, Slovenia, Lithuania, Luxembourg, Romania, Bulgaria, Malta, Croatia, Cyprus, Latvia, Greece, Sweden, and Belgium) detailing current MSW-Incineration capacity and utilisation, MSW-IBA generation, and MSW-IBA utilisation.
Environmental Services Association (ESA)	Publication of UK based data concerning MSW-Incineration capacity and utilisation, MSW-IBA generation, and MSW-IBA utilisation.
International Solid Waste Association (ISWA)	Publication of data concerning management of MSW-IBA from EU member states.
Eurostat	Publication of data concerning MSW generation and treatment (including incineration) for all EU member states.
UK Gov Pollution Inventory	Data concerning IBA production and Utilisation for the UK.

The desktop study was completed in three stages.

1. A review of academic and policy literature was completed concerning the generation, management and utilisation of MSW-IBA.
2. Data collected from the sources listed in Table 11, was used to identify trends in the generation and utilisation of MSW-IBA in the EU. Based on the data available, potential future trends in incineration (and thereby resultant production of MSW-IBA), in the context of the CEP, was calculated. Here, risk regarding technological lock-in was also briefly examined.
3. Review of policy documents (principally the CEP and the WFD), supported an exploration of utilisation routes (as a waste or non-waste) where the potential role of EoW criteria in facilitating further MSW-IBA utilisation and its contribution to waste-related targets was evaluated.

3.4.3 Stage 3: QUAN-qual basic explanatory sequential design method to address RQ4.

Stage 3 employed a basic explanatory sequential design method, which is a predominantly Quantitative assessment to address RQ4 (Section 2.6, pg. 81). Focusing on the UK LFT, this stage employed an expert opinion survey to examine how the introduction of the QFO (HoC, 2015) was received by stakeholders and its impact on material recovery and landfill diversion.

Expert opinion surveys allow for the remote collection of factual, attitudinal, behavioural and / or experience-based information from a relatively large number of people (Rowley, 2014). Traditionally, opinion surveys have been completed via telephone, mail or face-to-face (Fricker, 2002). Mostly used to conduct quantitative research, surveys are particularly useful when profiling a situation to develop overall patterns, when there is sufficient knowledge available to formulate meaningful questions, and where suitable (and willing) respondents can be identified and solicited. Furthermore, questionnaires can be used in predictive and analytical research to understand relationships between variables and to develop and test measurement scales (i.e. a set of statements or a scale to measure a complex variable) (Rowley, 2014).

Of course, other methods, such as interviews or Delphi, could have been employed to address this issue. Interviews allow researchers to employ a more flexible approach when engaging with a participant, often with a high return rate and generally leading to fewer incomplete answers (Alshenqeeti, 2014). Indeed, Alshenqeeti (2014) argues that interviews offer the researcher the opportunity to uncover a greater depth of information compared to surveys. Another approach, the Delphi method elicits expert opinions through a sequence of questionnaires, which are distributed and managed through a survey coordinator, and engages with specifically selected participants (Hirschhorn, 2018). Here, the use of a survey instrument rather than utilising interviews or employing the Delphi method allowed for an unrestricted number of participants to contribute, minimised respondent fatigue and simplified the methods of data analysis. Conversely, when employing the Delphi method, it is more efficient to interact with a smaller number of specifically chosen participants, where participants are interacted with multiple times and feedback is given between each stage (Hirschhorn, 2018). Small scale studies are also more suitable for the interview technique (Alshenqeeti, 2014). As both interviews and the Delphi method tends to collect fewer uniform data (than compared with a survey), often a qualitative coding process is required, which is more time and resource consuming than the quantitative data analysis employed within a survey (Hirschhorn, 2018; Alshenqeeti, 2014).

For this research, the survey instrument was an online self-administered questionnaire created and published using SurveyMonkey. In addition to the characteristics found in traditional survey methods (via telephone, mail or face-to-face), online surveys offer capabilities such as incorporation of multimedia graphics, automatic branching and an improved interface (Fricker, 2002). Benefits to employing online-based surveys include the access to new and broader populations with a wider base of characteristics, the ability to collect large volumes of data, savings in time and costs and the ability of participants to take part anonymously (Rice et al., 2017). Vaske (2011) suggests that while the use of online surveys in combination with other modes of research can contribute to decision-making within societal dimensions. However, caution is required to ensure methodological rigor, so that the results are representative of the target population and can be generalised to inform different situations. Indeed, Rice et al. (2017) note that disadvantages to online surveys include the inability to collect a truly random sample, fluctuating response and retention rates, use of financial (or other) motivations potentially leading to fraud, measurement of attitudes and perceptions rather than behaviours, and a lack of communication between respondent and researcher regarding instructions and clarification.

In this research, questionnaire development was informed by debates within industry literature (Balch, 2014; Coll, 2015; Goulding 2016, 2015 a, b), and supported by discussions at an open meeting, hosted by the Chartered Institute for Waste Management (CIWM) (4th March 2016 at the Cotton Exchange, Liverpool, UK), on the topic of fines management. Key issues identified at the CIWM meeting included the apparent lack of support for implementation and the reliability of the LOI testing regime, which mirrored those reported by Goulding (2016, 2015 a, b). Further issues, specifically regarding impact on the workplace such as investment, costs and administrative burden were noted by Balch (2014) and Coll (2015). Potential modifications to the QFO, including the introduction of additional tax bands or spike allowances, laboratory accreditation, and third-party sampling, were also proposed at the CIWM meeting.

The questionnaire was designed in accordance with the following structure (See Appendix 4: Expert Opinion Survey for a copy of the survey);

1 Respondent screening - A qualifying question was used to filter respondents so that only those impacted by the LOI testing regime could proceed.

2 Respondent profiling - To ascertain a respondent profile, and therefore level of representation, questions regarding which sector the respondent aligned to and their role (individual or organisational) regarding the production, management or testing of fines were asked, plus optional questions regarding job title and responsibilities.

3 LOI impact - The main body of the survey aimed to quantify any perceived impacts of the LOI testing regime on the workplace.

4 LOI opinions - Opinions were gathered regarding the LOI testing regime on its appropriateness, implementation and whether the level of current support provided was adequate.

5 LOI changes - Finally, opinions were gathered regarding the suitability of potential changes to the LOI testing regime that had previously been suggested by delegates at the ‘Fines talk’ and within industry literature.

The questionnaire employed closed questions with optional open comment boxes to instigate elaboration. Opinions were measured using Likert-type rating scales (Likert, 1932). Response format was selected to minimise the risk of introducing bias and followed the recommendation of Revilla et al. (2014) to employ a five point fully labelled scale with a neutral midpoint for opinion measurement in the general population. To ensure respondents were not forced to specify an opinion, thereby introducing a response bias (Friedman and Amoo, 1999), ‘don’t know’ and ‘not applicable’ (N/A) options were also included. While such responses are commonly excluded from analysis, doing so without consideration of potential consequences can lead to biased results and lost information (Kroh, 2006; Wang, 1997).

An invitation to participate was sent to 311 individual email addresses, comprising 27 ‘Fines Talk’ delegates and 294 addresses identified from web searches for waste management organisations (within a 15-mile radius of 24 UK urbanisations), commercial laboratories offering LOI testing, and waste research groups. The questionnaire link, with accompanying invitation, was also featured in the CIWM newsletter, Skip Hire magazine, and member communications of the United Resource Operatives Consortium. The invitation informed respondents about; the purpose of the study, anonymity of responses, and intended publication of results with key recommendations. To enhance response rates an incentive was offered, whereby respondents could opt in to a prize draw. In total 44 complete responses were received in the period between 9th June to 1st August 2016. This is consistent with similar surveys within waste management, which have received 12-35 responses (Eskandari et al., 2012; Glew et al., 2013). Reflecting on response rates, this survey achieved a lower response rate (14%) than seen in a similar study (34%) published by Glew et al. (2013). While response rates within probability sampling range from 30% to 85%, for studies that employ non-random sampling, i.e. targeting respondents with specific knowledge / experience, the reporting of response rates is not that common (Glew et al., 2013).

Quantitative data from the closed questions were analysed using Microsoft Excel 2013 and SPSS (v.22) to produce frequency distributions and to test for differences between stakeholder groups. There is marked variation in practice and debate in the literature regarding the appropriate statistical analysis of Likert-type data (Bishop and Herron, 2015; Carifio and Perla, 2008; Jamieson, 2004). As this study is exploratory in nature, with analysis carried out at the level of individual questions, a conservative approach was adopted, and the data was treated as ordinal, with the non-parametric Pearson's Chi-Square (X^2) statistic used to test for differences between groups (Jamieson, 2004; McHugh, 2012). X^2 is a non-parametric statistical test that reports the significance of differences found between distinct sets of data. It is particular useful, as in this study, when the variables are ordinal, study groups are an unequal size and data is measured at an interval level. It assumes that data is presented as frequencies, variables are mutually exclusive, and there is a limit of one response per respondent (McHugh, 2012). Unless otherwise stated, differences between groups were insignificant. Qualitative data (comments from open comment boxes) were used to enrich the quantitative responses and to identify areas of agreement and conflict.

3.4.4 Stage 4: Qualitative method design to address RQ5 and RQ6.

Stage 4 employed a workshop to address RQ5 and RQ6 (Section 2.6, pg. 82) in order to smooth the transition to the circular economy. First, limitations to current waste management policies that may create barriers to the circular economy were identified. Then potential solutions to overcome these barriers, specifically focusing on the concept of readiness was explored.

A workshop is where a group of people come together to address a domain-specific issue, through knowledge acquisition, creative problem solving, innovation and/or learning (Ørngreen and Levinsen, 2017). While similar in approach to a focus group, workshops differ in a number of ways. The first is the number of participants, where a focus group to seeks to recruit 6-8 participants, a workshop may include more. In this case, the workshop recruited 16 participants. Second, participants are preselected within a focus group to enable discussions to be based on a specific topic, of which all participants would have some experience of. Workshops can be open to a wider range of participants (not as prescriptive). The third difference relates to outcomes, in a focus group the aim of the activity is to produce a collective narrative based on experiences and knowledge. Whereas, a workshop allows for creativity and aims to identify a solution to an issue, through participatory activities (Liamputtong, 2011; Krueger and Casey, 2000; Hennink and Leavy, 2013). As a research methodology, a workshop fulfils the "research" purpose of collecting and producing reliable and valid data while fulfilling the expectations of the participants in that they will achieve something related to their own interests (Ørngreen and Levinsen, 2017). Basic features of a workshop (Ørngreen and Levinsen, 2017) and how this workshop adheres to them are presented in Table 12.

Table 12: Basic features of a workshop (Ørngreen and Levinsen, 2017) and application to Circular Economy Readiness workshop.

Basic features	'Circular Economy Readiness' workshop
An event organised over a limited duration.	**Workshop was held in a short (1 hr 20 mins) 'networking' session.**
Participants share a common domain e.g. employed in the same field / sector	All participant, as delegates of SUM 2018, had a connection/interest in waste management and resource efficiency.
Organisers have experience in the domain	**Organisers where experienced in the domains of waste management, energy/carbon management and environmental management.**
Groups are kept small to promote participation	During the activities, participants were split into two groups of five and one group of six.
Participant actively participate, and influence the direction of the workshop	**As a participatory workshop, each group had the opportunity to feedback during the session.**
Both organisers and participants expect an outcome.	Scoping activity sparking debate and discussion.

The workshop entitled 'Circular Economy Readiness' was held in May 2018 at the Congress Centre Papa Giovanni XXIII, Bergamo, during the Fourth Symposium on Urban Mining and Circular Economy (SUM 2018). Across three days, SUM 2018 engaged a range of stakeholders from research, industry and policy to discuss topics related to waste management, urban mining and the circular economy. An abstract describing the workshop was made available to delegates both on the symposium website before the event, and within the proceedings during the symposium.

The workshop was based on two activities.

1 First, a scene setting activity required each group to discuss how the waste and resource management sector could contribute to the circular economy, with each sharing what they believed were the most significant issues (both immediately and in the future).

2 The second activity was split into two parts:

2.1 The first asked participants to explore potential barriers within the waste and resource management sector that may impede the circular economy. To aid conversation, general barriers to the circular economy (non-waste and resource management specific) as identified in Table 1 (Section 2.4.5) were presented to the participant groups.

2.2 The second part asked the groups to suggest solutions to overcome barriers (identified in activity 2.1) in 'readiness' for the circular economy. As an optional activity, a simple Ease / Effect grid was provided to assess any suggestions based on ease of implementation and overall effectiveness.

Here, similarities between the barriers to the circular economy used in this study and the factors used in a PESTLE[4] analysis are acknowledged. A PESTLE analysis can be used as a tool to identify external macro forces that influence organisations (OCM, 2016). As it does not consider forces at a meso or micro level (as required by the circular economy) or internal factors, a PESTLE analysis was not considered appropriate for this study. Instead, the use of the barriers, which address all levels of engagement (macro, meso and micro) and include both internal and external factors was utilised as a way to encourage and structure discussions.

To conclude the workshop, all participants were asked to vote "yes", "no" or "maybe" on whether the concept of 'readiness' could be applied to the waste and resource management sector in the context of the circular economy.

Table 13 presents a breakdown of the workshop participants categorised by sector type, location and professional position. Of the fifteen respondents that provided

[4] An analysis tool that considers Political, Economic, Social, Technological, Environmental and Legal factors. (OMC, 2016)

their job title and location, all held professional positions (ONS, 2010) and the majority were from the EU, with representatives from Asia and the Americas. Overall, the participant profile demonstrates that while all were connected to the waste and resource management sector (as indicated by their attendance at SUM), participants encompassed a range of experience, viewpoints and priorities. During the workshop, the sixteen participants were asked to work in two groups of five and one group of six.

Table 13: Breakdown of workshop participant profiles

Sector type		**Location**		**Professional position**	
Academic	11	Brazil	1	Group 1 – Mangers, Directors and senior officials	1
		Japan	1		
Non-academic	4	Kazakhstan	2		
		Philippines	1	Group 2 – Professional occupation	12
		European Union	9		
		Italy	*(5)*	Group 3 – Associate professionals and technical occupations	2
		Netherlands	*(1)*		
		UK	*(3)*		
		United States of America	1		

3.5 Ethical considerations

It is important to consider ethics in the planning, undertaking and dissemination of research, as they serve as a mechanism to protect the rights of participants. This includes the elimination of unnecessary harm, (where appropriate) adequate reassurances of confidentiality, and ensuring appropriateness of methodological approaches (McKenna and Gray, 2018).

There were no significant ethics issues identified for this study. As this study gathered information and data from participants (i.e. during the online survey and stakeholder workshop) ethical consideration was given, with institutional (from Manchester Metropolitan University) ethical approval achieved (ref: SE161781C).

Where participants contributed to this research, consent was procured via a consent form, and a participant information sheet was used to provide information regarding the study and terms of participation, with an option to review, and withdraw, from the research without any explanation (for examples see Appendix 5: Example ethics documents). All data collected from participants was stored securely on a password protected computer, not shared with any third party and anonymised before analysis. Any activities carried out after May 2018 (workshop), also adhered to General Data Protection Regulations regarding personal data.

CHAPTER 4: In the search for effective waste and resource management policy – Alignment of UK waste strategy with the circular economy.

This chapter presents the results of a document analysis and addresses RQ1 and RQ2 (Section 2.6, pg. 81) by examining the circularity of current waste strategy within the UK and identifying examples of good and bad practice.

The initial analysis within this chapter has been published in the peer-reviewed journal, Detritus (*see* Appendix 2: Fletcher and Dunk, 2018).

4.1 Introduction and chapter outline

Waste policy has a significant role to play in the transition to, and the implementation of, the circular economy. The EU has promoted the transition to the circular economy as a major policy objective, most recently within the publication of the CEP.

A content analysis was used to assess the current waste management strategies of the four devolved administrations of the UK. Based on the circular economy framework, adapted from Kirchherr et al. (2017), and in light of the literature reviewed, the content analysis focused on the following themes; circular economy aims, circular economy core concepts and principles, and enablers of the circular economy, with a particular focus on the promotion of the waste hierarchy as an operationalisation principle and the inclusion of stakeholders.

Section 4.2 presents results pertaining to the context and overarching vision presented by each document. These results are accompanied by population and waste statistics for the document year and for 2016. Section 4.3 presents results concerning the inclusion of circular economy aims, circular economy core concepts and principles, enablers of the circular economy and stakeholders within the six documents. Section 4.5 discusses the six documents in light of implementation of EU policy and future implications. Finally, this chapter makes recommendations regarding improvements to UK waste management strategy that will aid the transition to the circular economy.

4.2 Comparison of documents' context and overarching vision

Table 14 presents a summary of the separate (England and Wales) or combined (Scotland and NI) waste management strategy (WMS) and waste prevention plan

(WPP) documents for each home nation. Details include the volume of text analysed, the context, and the overall vision, alongside population and waste statistics for the document year and for 2016 (DEFRA, 2017).

Table 14: Summary of UK home nations population, waste generation and management statistics, national waste management strategy (WMS) and waste prevention plan (WPP) documents.

	England		Scotland		Wales		Northern Ireland	
Year	**2013**	**2016**	**2010**	**2016**	**2010**	**2016**	**2013**	**2016**
Population	53.9m	55.3m	5.3m	5.4m	3.0m	3.1m	1.8m	1.9m
Waste generation(i)	400 kg	410 kg	490 kg	440 kg	450 kg	420 kg	430 kg	450 kg
Recycling rate	44.2%	44.2%	32.5%	42.8%	44.0%	56.7%	41.5%	43.0%
Landfill rate(ii)	25%	21%	41%	30%	33%	16%	24%	27%
Document	**Waste Management Plan for England**	**Prevention is better than cure. The role of waste prevention in moving to a more resource efficient economy.**	**Scotland's Zero Waste Plan**		**Towards Zero Waste One Wales: One Planet**	**Towards Zero Waste. One Wales: One Planet. The Waste Prevention Programme for Wales.**	**Delivering Resource Efficiency**	
Type	WMS	WPP	WMS / WPP		WMS	WPP	WMS / WPP	
Total pages	42	52	59		92	82	68	
Pages analysed	38	37	46		59	61	51	
Paragraphs analysed	194	339	288		357	540	374	
Words analysed	10,943	14,380	13,746		13,768	16,464	19,604	
CE Terminology	zero waste		zero waste		zero waste		circular economy	
Context	Minimise environmental & human health impacts.		Economic growth & addressing climate change.		Social & cultural justice, climate change & limited resources.		Economic growth.	
Approach	Supports local authorities, highlights zero waste initiatives, and advocates lifecycle thinking.		Advocates long-term policy stability and effective resource use, acknowledges role of consumer behaviour and notes need for continued waste management.		Highlights that resource use should be within environmental limits. Engages citizens, business & industry, and notes legacy wastes.		Advocates implementation of waste hierarchy, recognises waste as a resource, and calls for increased integration and support across sectors and stakeholders	

(i) Municipal waste generation per capita per year (ii) Biodegradable municipal waste disposed to landfill as a % of the 1995 baseline.

4.2.1 Context and overarching vision of England’s waste strategy documents

Within both the WMS and WPP documents, the stated aim is to work towards a zero-waste economy as part of the transition to a sustainable economy. Where the WMS document defined a zero-waste economy as; one where material resources are reused, recycled or recovered wherever possible, and only disposed of as the last resort, and the need to reduce waste generation and ensure all materials are fully valued during their productive life (in addition to at end-of-life) was also recognised. However, focus of the two documents was found to be primarily on minimising the environmental and human health impact of waste generation and management, where this is achieved by supporting local authorities (and waste management companies) to prioritise recycling and recovery of waste materials. While the role of zero-waste initiatives was highlighted in both WMS and WPP documents, along with the promotion of life-cycle thinking and closed loop approaches, they provide little more than rhetoric regarding these ideas. For example, although it is implied within the WMS document that resources should be used efficiently, the document only introduces governmental drivers to achieve this, and places responsibility for creating more goods and services with fewer resources on businesses and industry. Likewise, this stance is mirrored in the WPP, which promotes the role of government as; being one to “get out of people’s hair”, and sets the conditions for the market, businesses, and local authorities to make the changes required to transition to a more sustainable economy.

4.2.2 Context and overarching vision of Scotland’s waste strategy documents

Scotland’s Zero Waste Plan defines a zero-waste Scotland as; one that makes the most efficient use of resources by minimising demand on primary resources. And instead of treating them as wastes, maximises the reuse, recycling and recovery of resources. It frames WMS within the context of economic growth and climate change, where resources are managed efficiently, economic opportunities are sought (and capitalised upon), waste materials are given a value, and greenhouse gas emissions are reduced. To do this, it advocates a transition away from a linear economy, long-term policy stability, and effective resource use. It also acknowledges the role of consumer behaviour, asking individuals and businesses to recognise and take responsibility for their actions. It recognises the need for continued WMS for the foreseeable future and promotes the reuse, recycling and recovery of resources from waste in line with the waste hierarchy.

4.2.3 Context and overarching vision of Wales' waste strategy documents

Towards Zero Waste – One Wales: One Planet (WMS) defines zero-waste as; an aspirational end-point where all waste that is produced is reused or recycled as a resource, without the need for any landfill or energy recovery. It, along with the WPP document, frames waste management in the broader context of social justice, cultural legacy, climate change and limited resources. Both WMS and WPP documents aim to create a pathway to where resource use is within environmental limits, society and culture prosper, and human well-being is maximised. To do this, both documents advocate sustainable consumption and production, optimisation of material utilisation, and reduced dependence on primary resources. The WMS document promotes a long-term framework that requires the engagement of citizens, business and industry. Here, citizens are asked to rethink and reconsider consumption patterns, and to become a recycling society. This is supported by the WPP, which introduces the 4E's model of behaviour change. This model prompts the Welsh government to:

1 engage with consumers and households directly,

2 enable measures that help consumers prevent or reduce waste,

3 encourage (via policy measures and the activities of local authorities) waste reduction at a household level and to switch consumption to products with lower ecological footprints, and,

4 exemplify best practice across supply chains through demonstration projects and green procurement.

Fostering cross-organisation collaboration, business and industry are also asked within the WMS document to consider the use of alternative materials, employ integrated product policy and employ initiatives to reduce associated emissions. It acknowledges the continued production of some wastes, and so advocates enhanced action on waste prevention, maximised recycling and near zero-waste to landfill strategies. It also notes the requirement to manage legacy wastes.

4.2.4 Context and overarching vision of Northern Ireland's waste strategy documents

The Delivering Resource Efficiency strategy aims to set a direction towards treating waste as a resource and using it more efficiently. This is positioned within the EU objective of moving towards a circular economy, and although no definition of a circular economy is given, it is noted that it requires a greater focus on waste prevention followed by an increase in recycling. This strategy is positioned in the context of economic growth, whereby sustainable waste management can promote green jobs, maximise opportunities, and contribute to a low carbon, circular economy. It identifies the need for both socially-responsible economic growth and global economic transformation to address depletion of finite natural resources and climate change. To do this, the document advocates the implementation of the waste hierarchy, recognition of waste as a resource, use of environmentally friendly technology and behaviours, and increased integrated support across sectors and between stakeholders.

4.3 Alignment of waste strategy documents against circular economy framework.

Development of the circular economy framework (Figure 16 in Section 3.4.1) allowed the systematic, yet simple, assessment of documents (see Appendix 6: Raw data – counts for document analysis for full counts). When circular economy aims, circular economy core concepts and principles (including promotion of the waste hierarchy), enablers of the circular economy, and the inclusion of stakeholders were considered, both similarities and substantial differences were found between the waste strategies of the UK home nations.

4.3.1 How well do the strategy documents align with circular economy aims.

All six documents made reference to economic prosperity combined with some other dimension(s) of sustainable development, variously referring to a ‘zero waste economy’ and a ‘sustainable economy’ (England – WMS / WPP, Scotland and Wales - WMS), a ‘low carbon economy’ and a ‘green economy’ (Scotland, NI, Wales - WPP) and a ‘prosperous society’ characterised by full employment and high value green jobs (Wales - WMS). High value green jobs were also mentioned to a lesser degree in the WPP document of England. However, the extent to which environmental quality, social equity, and future generations were considered was found to vary significantly.

With respect to environmental issues, the four WMS documents refer to environmental protection, with a strong emphasis on reducing climate change impacts found in the documents for Scotland, Wales (WMS) and NI. Climate change was also mentioned in the WPP document for England and to a lesser degree in the WPP document for Wales. Regarding environmental targets and ongoing assessment of strategies, Scotland and Wales (WMS / WPP) were the most progressive, going beyond the weight-based indices used within EU policy by adopting more challenging targets measured through a carbon footprint-based metric (Scotland) and ecological foot printing (Wales - WMS). While NI mentioned carbon foot printing, like England (WMS / WPP) it did not introduce any new targets or metrics to measure improvements.

While all six documents referred to safeguarding human health, and England (WPP), Scotland and NI made some reference to social benefits and well-being, the emphasis was less than that placed on environmental protection. Wales (WMS / WPP) was the only exception to this, with directly comparable prominence of environmental and social aspects of the circular economy, linking economic and social development with environmental quality, well-being, social justice and equality of opportunity.

All six documents made some reference to shaping the future (through decisions made now) and / or future waste management needs, where Scotland, Wales (WMS / WPP) and NI also made specific reference to future generations. Wales (WMS / WPP) had the strongest consideration of future societal needs (as indicated by the titles of the two documents), where the concept of living within environmental limits explicitly incorporates the time dimension to ensure enough resources are available to achieve a better quality of life for both present and future generations.

4.3.2 How well do the strategy documents align with the core concepts and principles of the circular economy.

All six documents included multiple references to resource efficiency, where the emphasis placed on this concept was comparable across Scotland, Wales (WMS / WPP) and NI, but significantly weaker for England (WMS / WPP). Scotland and Wales (WMS / WPP) clearly identified the need for large-scale changes to achieve their objectives (including changes to attitudes and behaviours, and acceptance of change), highlighting the role of policy and the public sector in driving this change. In comparison, NI made limited reference to the scale of change (although the need for behavioural change and the role of Government leadership in maintaining the pace of change were touched upon), while England (WMS / WPP) made no reference to the scale or type of change needed. Inclusion of other core concepts was variable and limited. Within the WMS documents, only England and NI made explicit reference to decoupling economic growth from resource use. However, reference to decoupling was made within the Wales WPP document, with limits to growth also recognised in both WMS and WPP documents. Only Wales (WMS / WPP) and NI cited the need for sustainable consumption and production. While Wales (WMS / WPP) and NI made multiple references to the need for life-cycle thinking and approaches, Scotland made only one reference to life-cycle thinking and England made seven references, the majority (6) being within the WPP document. In the case of England these references were simply to note that departure from the waste hierarchy could be justified by life-cycle thinking (rather than advocating life-cycle thinking as an underpinning concept to delivering resource efficiency).

4.3.3 Comparison of strategy documents with respect to promoting the waste hierarchy.

Figure 17 presents the occurrence of terms associated with waste hierarchy categories within the combined WMS and WPP documents of the UK home nations on both an absolute and per word basis.

While occurrence of the waste hierarchy categories differed widely between the four documents on an absolute basis, frequency counts were more comparable on a per word basis. Overall, the implementation of the full waste hierarchy across all documents is considered to reflect EU waste policy, with some differences in relative emphasis relating to the approach to transposition adopted by England and NI on one hand (“no gold-plating”, reactive) and Scotland and Wales on the other (“gold-plating”, proactive).

Recycling strategies (material recovery, anaerobic digestion, and composting) were dominant within the four WMS documents, where this national emphasis on recycling is likely driven by EU policy and targets that focus on recycling and landfill diversion (Mazzanti and Zoboli, 2009; Fisher, 2011).

Prevention strategies were the second most frequently cited within the WMS documents. Here, it is noted that differences in the counts of prevention terms will to some extent reflect the scope of the documents, where England and Wales both elected to develop separate WPP and therefore provided only an overview of intended prevention activities within the WMS documents. As would be expected, inclusion of prevention terms (reduce and prepare for reuse) was dominant in the two WPP documents. Nonetheless, inferences can be drawn from the presence or absence of any reference to different prevention imperatives and activities.

Furthermore, it is noted that the separate consideration of waste prevention strategies may have unintended consequences arising from a lack of joined up thinking between waste prevention and waste management activities.

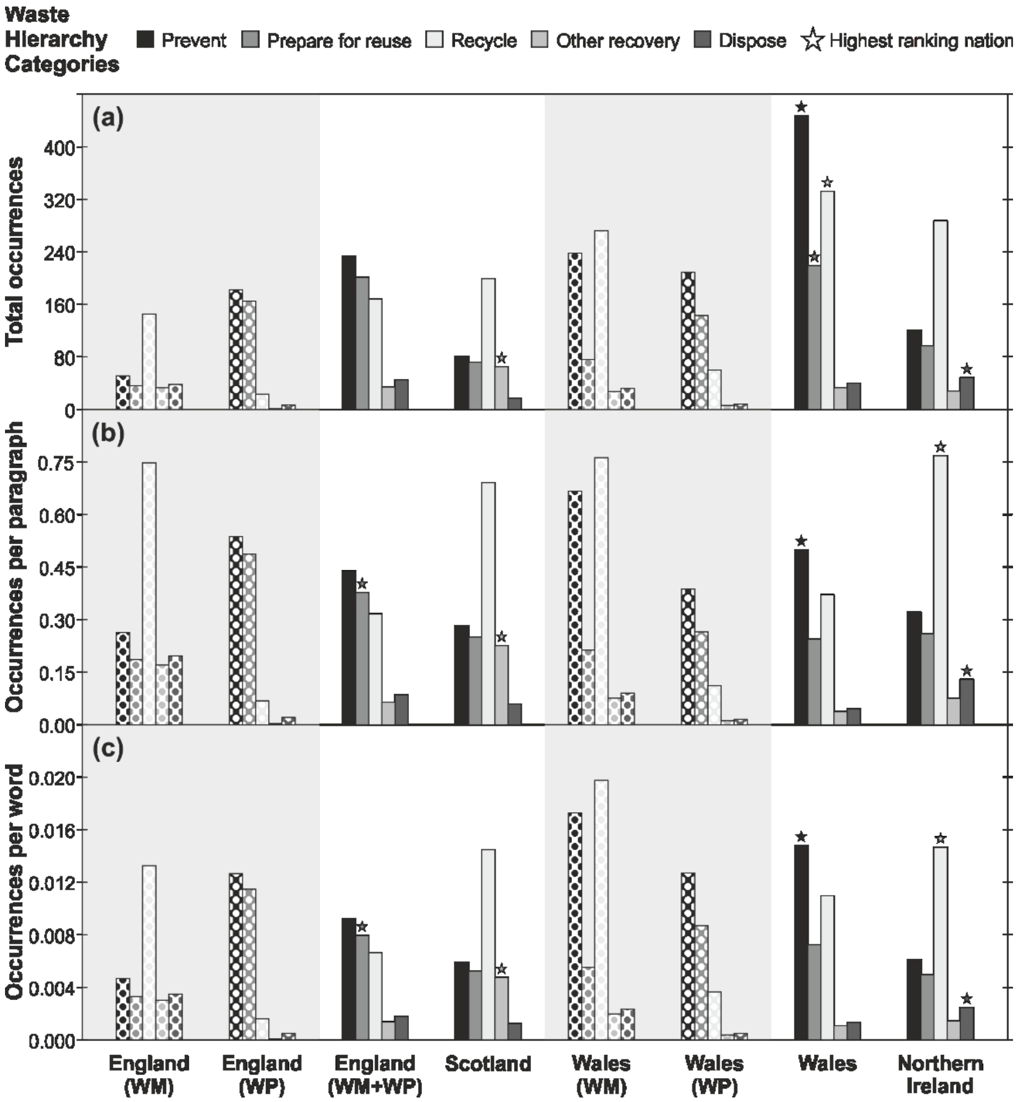


Figure 17: Representation of waste hierarchy categories in the waste strategy and waste prevention documents of the UK home nations on (a) total occurrences (b) occurrence per paragraph and (c) occurrence per word basis.

The majority of the prevention terms counted made general reference to the need to reduce waste and mirrored the terminology employed by EU policy. While all four WMS documents made some reference to activities associated with R0-R2 (Refuse, Rethink, Reduce), there was a much stronger emphasis on these imperatives in the Welsh document (particularly with respect to product design and the use of recycled materials), and this was also the only strategy to note the role of consumers (in buying less). Likewise, only Wales and Scotland included R3 activities (Reuse), and only Wales included re-servitising and re-modelling business.

The least priority was given to “Recover” terms in all documents except Scotland (where it ranked fourth ahead of disposal). However, reference to incineration within the Scottish document was found to be in conjunction with a potential ban on incineration, where the context was to ensure strategies were moved further up the waste hierarchy (not just from disposal to incineration).

The use of continued disposal was found to be a higher priority for the English document (ranked third within this document) when compared with Wales and NI, where it ranked fourth and Scotland where it was given least priority. Interestingly, it is noted that when counts included reference to landfill diversion, the majority of mentions in the Scotland (77%), Wales (56%) and NI (59%) WMS documents were concerned with diversion, whilst in the English WMS document the majority of mentions (66%) were concerned with the continued use of landfill.

4.3.4 Comparison of strategy documents with respect to enablers of the circular economy and stakeholder engagement.

Comparison of the six documents found variation in the dominant types of enabling measures and instruments employed to drive market changes. While all six documents made some reference to investment, other fiscal (dis)incentives, green procurement, extended producer responsibility, and the use of voluntary agreements and standards, the relative emphasis differed. Scotland had a strong emphasis on investment, England (WMS / WPP) dominantly referred to extended producer responsibility followed by investment, Wales (WMS / WPP) promoted the use of green procurement followed by extended producer responsibility, while NI focused on voluntary agreements / standards and extended producer responsibility. Furthermore, Wales (WMS / WPP), and to a lesser extent Scotland and NI, encouraged the development of markets for recyclates and reuse. With respect to measures that addressed consumer behaviour, the WMS document for England was found to be severely lacking, however the WPP did promote public engagement to some extent. In comparison, Scotland, Wales (WMS / WPP) and NI all promoted the use of education, communication, and consumer engagement and awareness campaigns to change attitudes. These documents also incorporated measures that required the involvement of other sectors as well as the waste management industry.

Figure 18 presents the occurrence of terms associated with stakeholder categories within the WMS and WPP documents of the UK home nations on both an absolute and per word basis.

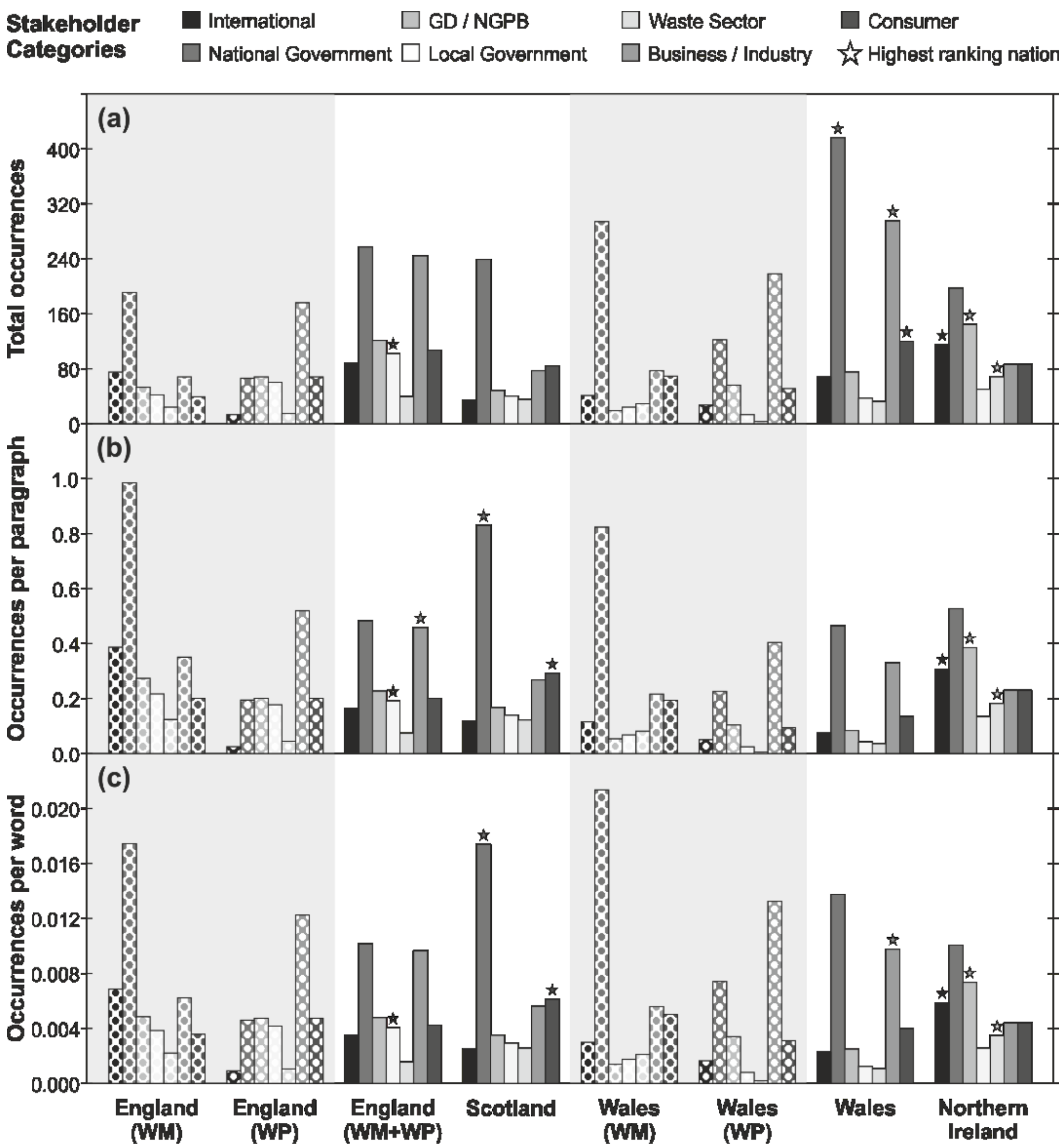


Figure 18: Representation of stakeholder categories in the WMS and WPP documents of the UK home nations on (a) total occurrences (b) occurrence per paragraph and (c) occurrence per word basis.

Substantive differences were found between the four documents with respect to the engagement of different stakeholder groups, as detailed in Table 15 (nation-specific stakeholder engagement tables can be found in Appendix 7: Stakeholder Responsibilities – England Appendix 8: Stakeholder Responsibilities – Scotland Appendix 9: Stakeholder Responsibilities – Wales and Appendix 10: Stakeholder Responsibilities – Northern Ireland).

Table 15: Stakeholder responsibilities as reported by the four home nations.

(I: International; N: Nation; GD/NGPB: Government Departments & Non-governmental Public Bodies; R: Regional; WM: Waste sector; OBI: Other Business and Industry; C: Consumers)

<table>
<tr><td>England</td><td>England only (N) Set targets, provide support and guidance. Encourage sustainable thinking . Produce quality standards for recycled materials. Identify suitable locations for future facilities. Drive behaviour change (GD/NGPB) Provide funding for schemes. Organise voluntary sector agreements. Provide advice and guidance. Provide data and evidence regarding current and future waste management activities. (OBI) Provide private financial initiatives. (C) It is acknowledged that consumers are the main contributors to waste generation and that a change in behaviour would contribute to national objectives; however, they are not held responsible or accountable by any policy mechanism.</td><td rowspan="2">Scotland only (I) Promote the waste hierarchy and high-quality recycling. (N) Develop programmes that promote the waste hierarchy and best available techniques. Introduce measures that value resources, and develop secondary materials markets. Provide guidance, tools and support to encourage good practice, and promote long-term stability, eco-design and investment. Stimulate behaviour change by strengthening market confidence, developing measures to influence behaviour, and providing reliable information. (GD/NGPB) Provide guidance for the delivery of zero waste plans and policies. Enable efficient resource use. Contribute to the design of non-waste facilities / activities. (R) Provide leadership in areas of influence and to achieve value for money with respect to procurement. (WM) Partial responsibility for compliance. Develop good practice commitments. Adhere to audits, and report information concerning compositional data, services provided, and voluntary opportunities. Public engagement. (OBI) Responsibility for investment in capacity and infrastructure. Adhere to good practice commitments. Develop innovative technologies. Participate in awareness campaigns. Improve understanding and usage of resources. (C) Active participation in programmes and initiatives. Involvement in waste infrastructure planning process. Implored to be enthusiastic and take action.</td></tr>
<tr><td>Scotland</td><td>England & Scotland (I) Require the collection of data to assess progress. (OBI) Responsibility for reducing waste generated under their control through resource efficiency and sustainable product design. Contribute to future waste strategy by providing evidence regarding current activities and responding to consultations. (C) Provide evidence on current waste management activities and can respond to consultations.</td></tr>
<tr><td>Northern Ireland</td><td>England & NI (GD/NGPB) Promote and support inter-stakeholder collaboration. (R) Collaborate cross sectors, industries and third sector to fulfil responsibilities and tackle poor compliance. (WM) Where appropriate, develop actions to meet quality standards and change behaviours to contribute to national objectives. Contribute to future waste strategy by providing evidence regarding current activities and responding to consultations. (OBI) Develop and participate in voluntary initiatives.</td><td rowspan="2">Scotland & Wales (N) Review / monitor progress with respect to targets and the success of implemented measures and initiatives. (GD/NGPB) Develop and implement programmes, campaigns and tools. (WM) Address skills gaps and increase the number of green jobs. Responsibility regarding investment in capacity and infrastructure considering national policy. (C) Encouraged to recognise and rethink their influence within the workplace and at home regarding procurement and consumption, taking responsibility for their actions.</td></tr>
<tr><td>Wales</td><td>England & Wales (WM) Provide waste collection services that are regular, efficient and affordable, working in partnership with local authorities and other regional stakeholders.</td></tr>
<tr><td></td><td>England</td><td>Scotland</td></tr>
</table>

Table 15 continued.

<table>
<tr><td colspan="2">ALL
(I) Set overarching legislation and objectives. Introduce broad programmes to assist with meeting objectives. (N) Transpose international legislation into national objectives and ensure complience with international policy. Collect and publish information on waste flows, commodity prices, and legislative proposals, and provide such information to stakeholders (GD/NGPB) Initate and respond to consultations regarding marco-level studies, legislation, strategies and spacial aspects. Implement, monitor and enforce legislation and policy. (R) Provide evidence to consultations. Adhere to national and international legislation. Planning and implementation of waste collection and managment schemes. Collect and report data on compliance, audits, illegal activities and planning. (WM) Adhere to national and international legislation and relevant environmental permit conditions. (OBI) Adhere to national and international legislation, and sector specific domestic targets.</td></tr>
<tr><td rowspan="2">Wales only (N) Provide a long-term vision to reduce Wales' ecological footprint to within environmental limits. Apply key principles (precautionary principle, polluter pays principle, proximity principle, waste hierarchy, and equality of opportunity). Introduce penalties for non-compliance. Grant powers to regulators for enforcement. Explore initiatives. Raise awareness. Provide advice and support regarding secondary materials markets, IPP, and waste infrastructure. Promote broader themes of zero-waste, sustainable development and citizen empowerment. (GD/NGPB) Support local capacity/ infrastructure plans and skills development. Provide information on technical requirements. Assess skills gaps. Encouraged to adopt sustainable waste management practises and drive change through procurement. (R) Support alternatives to landfill and encourage systems that treat waste as a resource to ensure greater consistency in recycled materials. (WM) Implement waste strategy. Introduce programmes/initiatives that promote closed loop recycling. Establish integrated networks of waste facilities. (OBI) Develop and implement voluntary arrangements that consider the polluter pays principle, extended producer responsibility and IPP. Exert influence through procurement activity. Employ eco-design. Contribute to feedback mechanism by recording and submitting data. Assessing skills gaps within their own sector. Share responsibility for waste generated and future proof against future resource competition. (C) Encouraged to develop local exchange schemes and participate in national educational and engagement schemes. Contribute to the well-being of Wales, resource efficiency and waste reduction.</td>
<td>NI only (I) Provide access to officials to support implementation of programmes and objectives. Identify financial and non-financial opportunities. (N) Develop (all-island) compatible and complementary policy. Develop domestic re-use and voluntary quality assurance schemes. Reduce burdens on business and support resource efficiency. (GD/NGPB) Use a suite of penalties and sanctions to ensure compliance. Grant funds for schemes and initiatives. Develop programmes and educational campaigns. Explore and exploit economies of scales. (R) Use powers to improve the quality of the environment. (WM) Develop and utilise programmes and investment schemes to introduce innovative waste collection schemes and integrate facilities on an all-island basis. Implement codes of practice. Support local authorities and communities to adhere to the waste hierarchy. Collect and report data regarding specific waste streams. (OBI) Build market confidence. Consider best available techniques. (C) Participate in campaigns. Promote social enterprise along with green jobs. Instigate improvement through public engagement and social acceptance.</td></tr>
<tr><td>Wales & NI (N) Develop sector plans (including voluntary targets) or propose sector-specific targets (GD/NGPB) Encourage investment in innovative technologies and support market development.</td></tr>
<tr><td>Wales</td><td>Northern Ireland</td></tr>
</table>

While, England (WMS / WPP) and NI tended to focus on macro-level stakeholders, particularly those concerned with cities and regions, Wales (WMS / WPP) and Scotland also placed equal emphasis on micro-level (e.g. consumers, producers, designers) and meso-level stakeholders (e.g. sectors, community groups). In light of the argument made by Su et al. (2013), Wales and Scotland would be the most successful in the implementation of the circular economy as they include all three levels of stakeholders.

Notable comparisons include the similar prominence of national stakeholders in all six documents. This is expected given the nature of the documents, i.e. published by the devolved governments and being primarily concerned with domestic strategy. While there was differing prominence, the responsibilities of GD / NGPB and international stakeholders were similar, reflecting the former's role as regulators to ensure compliance and issue sanction where necessary and the latter's role to provide and enforce overarching objectives and targets. With respect to international stakeholders, England (WMS) and NI were found most likely to engage, this being due to existing waste export routes (England) and the presence of a land border with the Republic of Ireland, together with ambitions of an all-island waste strategy, in NI. Scotland and Wales (WMS / WPP) also referred to using their influence with national and international stakeholders to shape future goals.

Perhaps the starkest difference between the four documents was the inclusion of consumers, or lack thereof, where they held no responsibilities within the English WMS document other than to receive waste management services and potentially participate in initiatives and information collection schemes. Here, it is noted that within the WPP document for England, the consumer was included to a larger degree, but responsibilities remain aligned to those identified in the WMS document. This contrasts with the Welsh (WMS / WPP) and Scottish documents that, to varying degrees, hold the consumer responsible for their level of consumption and waste generation, and asks them to actively engage and participate in waste reduction programmes. With respect to industry and business groups, Scotland and Wales (WMS) encouraged greater engagement with circular economy ideals when compared to England (WMS) and NI. However, these stakeholder groups received greater inclusion within the WPP documents for Wales and England. Further differences were found when scope of engagement with these stakeholders were considered. Within the documents for Scotland and

Wales (WMS / WPP), industry and business were asked to be innovative, and were encouraged to develop and take opportunities that would incorporate circular economy thinking into their business models. In contrast, in England (WMS / WPP) and NI, engagement with industry and business was limited to providing policy, regulation and voluntary agreements (these were present in all documents) to which business and industry should adhere. Interestingly, NI placed an emphasis on the role of business and the implementation of environmental management systems to improve environmental performance, where this consideration did not feature in the other strategies.

4.4 Implementation of EU policy and future implications

Analysis of these six documents illustrates points made by García Quesada (2014) that the amount of discretion given to member states to implement EU objectives can lead to significant differences (and levels of success) in national implementation. Where England has transposed EU policy with “no gold-plating” (minimum requirements), Wales in particular can be argued to have had more success in using the “gold-plating” (going beyond minimum requirements) approach (Anker et al., 2015). Indeed, it is noted that the English documents incorporate and combine existing policies without introducing new approaches. This is fundamentally different to Scotland, Wales and NI who all aim to set a strategic direction. Having said that, while NI does set a strategic direction, like England, its emphasis remains on meeting the requirements set out by the EU. In comparison, Scotland and Wales appear much more proactive, extending their strategies beyond EU requirements, influencing policy not in their direct control to achieve their individual goals, and understanding the need for, and instigating, change. This observation agrees with Winans et al. (2017) and Scotford and Robinson (2013), regarding the superiority of Welsh and Scottish environmental policy within the UK, in that the strategies they promote are more progressive, but like England and NI they continue to refer to overarching objectives set by the EU.

Differences in approach may have contributed to differing levels of success with respect to EU targets. This disagrees with Andrews and Martin (2010) who found no variation in waste management services between the four devolved administrations, attributing this to objectives being set at a supranational level, i.e. by the EU. This analysis found that in the period since WMS publication (2010 for Scotland and Wales; 2013 for England and NI), both Scotland and Wales have implemented strategy that has reduced waste generation, increased recycling rates and reduced landfilling of Biological Municipal Waste (BMW), with Wales achieving a landfill rate reduction of over 50%. In comparison, waste generation in England and NI has increased and varying results are reported for recycling and landfilling. In England, while the landfill rate has been reduced, the rate of recycling has plateaued, remaining at 44.2%. Whereas in NI, both recycling and landfill rates have increased. With respect to EU targets, all four nations have achieved the landfill directive of no more than 55% BMW landfilled by 2016, and Wales has already surpassed the recycling rate target set by WFD of at least 50% by 2020. While it could be suggested that Scotland and NI are progressing towards meeting this target, the plateauing of England's recycling rate could suggest its current strategy may struggle.

Overall, limitations for the six documents are a continued focus on waste management rather than resource utilisation, and the reliance on EU targets and objectives to set national priorities. This issue may become more pertinent after Brexit due to an absence of overarching UK strategy, which would have previously been supplied by the EU. While it appears that Wales and Scotland do have long-term policy objectives (including to future proof and avoid 'lock in') and have started the process of incorporating waste management and prevention strategy into the broader context of resource management and sustainable development, this is generally absent from the English (and therefore overall UK) strategy. This lack of coherence in objectives and enforcement across the four home nations of the UK may lead to further complications in the future. As suggested by Scotford and Robinson (2013), diverging amendments enacted by devolved administrations may lead to increased fragmentation and disparity of UK environmental policy.

4.5 Chapter Summary

Like all member states, the UK is required to transpose EU strategy into national strategy and develop mechanisms to achieve targets and objectives. A key characteristic of the UK is the role of the devolved administrations of its home nations (England, Scotland, Wales and Northern Ireland), whom all have a responsibility to develop their own waste management strategies that achieve individual goals but also contribute to the UK achieving objectives set by the EU. To aid the transition to the circular economy, the EU has developed the CEP, which in the future will shape UK waste management strategy. However, there may be potential ramifications from the decision of the UK to leave the EU (Brexit). Here it is thought that in the short to medium term, adoption of the CEP will provide overarching objectives and targets for the UK due to transposition into national policy. However, in the long term, objectives will depend on changes implemented by the UK government and the devolved administrations.

This chapter used a conceptual framework (based on circular economy literature) to assess the inclusion of circular economy aims, circular economy core concepts and principles, enablers of the circular economy, and stakeholder engagement within six governmental documents (waste management strategy documents for England, Wales, Scotland and NI and waste prevention plan documents for England and Wales). Differences in interpretation and implementation of current EU objectives were identified across the four home nations, with Wales and Scotland promoting more progressive strategies (such that resource management is favoured over waste management and lock-in is avoided through appropriate future-proofing initiatives) and showing greater improvement regarding EU waste targets. This confirms the conclusion of previous studies that Wales and Scotland currently have the most progressive waste management strategy of the four home nations.

An additional point raised in this chapter, which is specific to the potential risks of Brexit is the ongoing monitoring and enforcement of objectives and targets. Where this has previously been supplied by the EU, such mechanisms may not be present in the future unless a UK wide enforcement system is adopted. This may become an area of contention if Scotland and Wales, who already promote progressive waste strategies, were to diverge further. To address this issue, it is imperative that strong cross-party support is gained for long-term circular economy objectives both within each devolved parliament and across the UK. This would prevent the return of waste strategy politicisation that was successfully overcome on joining the EU due to the primacy of European law.

CHAPTER 5: To burn or not to burn - Questioning waste and resource management policy and practice.

This chapter examines potential barriers within existing policy and practice that may limit the ability to transition to a circular economy, focusing on one residual waste: MSW-IBA (RQ3; Section 2.6, pg. 81).

5.1 Introduction and Chapter overview

While the use of advanced technologies has improved waste and resource management immensely, it may have unintended consequences that limit the ability of nations to transition to the circular economy. Focusing on the use of incineration as a waste management strategy within the EU, this chapter presents a desktop study that highlights the implications of short-term targets and poor harmonisation.

This chapter reviews the production, management and utilisation of MSW-IBA in light of increasingly stringent landfill diversion and material recovery targets. To do this, trends in EU incineration and the risk of lock-in are first examined, followed by the exploration of routes for MSW-IBA utilisation. All of which is discussed in light of near-term targets, long-term objectives and the transition to the circular economy.

5.2 Trends in the use of incineration across the EU, and implications concerning the risk of lock-in.

This section focuses on the generation and utilisation of MSW-IBA in the EU. Trends in incineration rates and resultant production of MSW-IBA are discussed in the context of EU waste policy and the risk of lock-in.

5.2.1 Trends in the utilisation of incineration as a waste and resource management strategy within the EU.

A summary of the treatment of MSW in the EU from 1995 to 2015 is presented in Figure 19. The impact of the LD and the WFD can be clearly seen. A combination of increased recycling (25 to 70 Mt/yr.), composting (14 to 40 Mt/yr.), and incineration (32 to 64 Mt/yr.) has more than halved the amount of MSW being sent to landfill (141 to 62 Mt/yr.) between 1995 and 2015 (Eurostat, 2017). However, while the expansion of incineration (particularly within wealthy northern countries such as the Netherlands, Denmark, Germany, Sweden and the UK) has helped to drive diversion of waste from landfill, if it were to continue apace, it could place the more stringent landfill diversion and material recovery targets of the CEP out of reach.

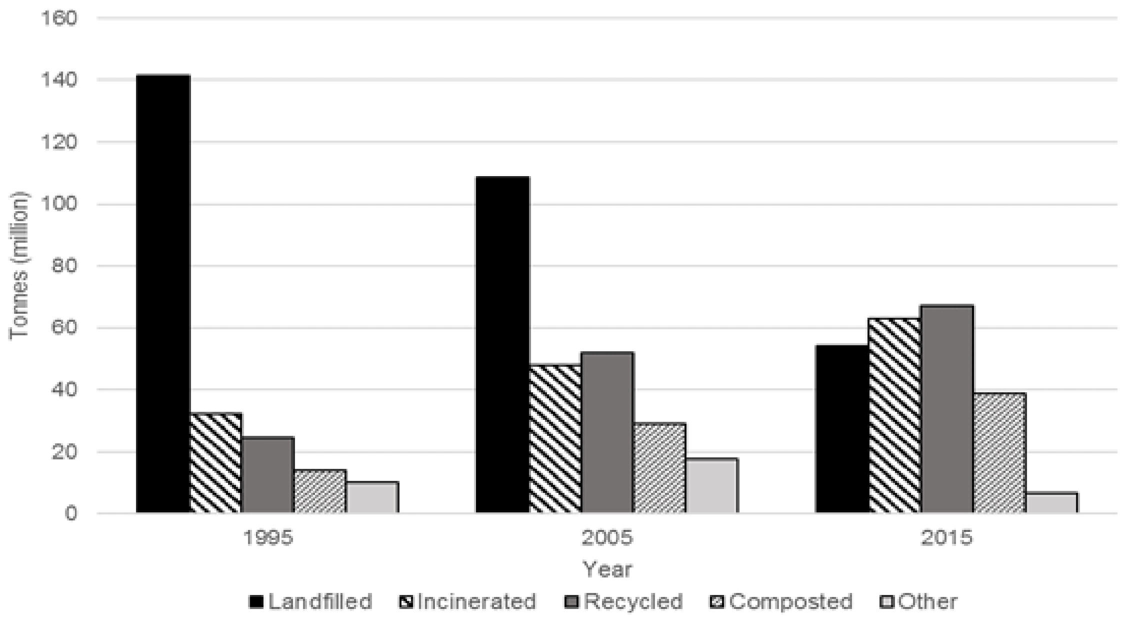


Figure 19: Summary of MSW treatment in the EU, where combined EU values for 1995, 2005 and 2015 are presented. Based on Eurostat (2017).

5.2.2 Assessing the risk of lock-in with regards to incineration

Table 16 presents MSW generation, disposal to landfill and incineration rates for EU member states in 2015, while Table 17 presents a compilation of available data regarding MSW-IBA generation and utilisation. This data is used to explore the potential consequences of member states adopting incineration as a key strategy to meet the more stringent diversion target introduced by the CEP of <10% MSW to landfill by 2035 (Table 3; Section 2.5.2).

Table 16: MSW generation and treatment for EU member states in 2015.

MSW GENERATION AND TREATMENT (2015)					
Country	Generation	Landfill		Incineration	
	kt	kt	% msw	kt	% msw
Germany	51,046	106	0%	15,973	31%
France	33,399	8,603	26%	11,600	35%
UK	31,567	7,124	23%	9,907	31%
Italy	29,524	7,819	26%	5,582	19%
Netherlands	8,855	125	1%	4,152	47%
Denmark	4,485	51	1%	2,359	53%
Spain	20,151	11,101	55%	2,342	12%
Sweden	4,377	35	1%	2,241	51%
Belgium	4,708	43	1%	2,043	43%
Austria	4,836	144	3%	1,833	38%
Poland	10,863	4,808	44%	1,439	13%
Finland	2,738	315	12%	1,312	48%
Portugal	4,710	2,307	49%	974	21%
Czech Rep.	3,337	1,755	53%	590	18%
Hungary	3,712	1,991	54%	525	14%
Ireland	2,693	1,028	38%	427	16%
Estonia	473	35	7%	243	51%
Slovakia	1,784	1,226	68%	191	11%
Slovenia	926	210	23%	158	17%
Lithuania	1,300	702	54%	150	12%
Luxembourg	356	63	18%	121	34%
Romania	4,895	3,522	72%	116	2%
Bulgaria	3,011	1,994	66%	82	3%
Malta	269	241	90%	1	0%
Croatia	1,654	1,319	80%	0	0%
Cyprus	541	403	74%	0	0%
Latvia	857	494	58%	0	0%
Greece	5,585	4,507	81%	0	0%
TOTAL	242,652	62,071	26%	64,361	27%

Greytext indicates data is absent for one or more years. For five-year time periods, the average of available years was taken. For 2015, the most recent available data is presented (Portugal = 2014, Ireland and Greece = 2012).

First, the data in Table 16 demonstrates that incineration currently plays a key role in achieving landfill diversion, where incineration rates are substantially higher in the seven member-states who already meet the revised target (range 31-53%, median 47%, weighted average 37%), than in the 21 member-states who do not (range 0-48%, median 14%, weighted average 22%). Thus, if the current trend of increasing incineration in order to achieve landfill diversion targets is continued, then for a first order estimate, it seems reasonable to assume that the average incineration rate across all member states would increase from 27% to ca. 42±5%

Table 17: Generation and utilisation of MSW-IBA reported by seventeen EU member states, including total amount of MSW thermally treated (TT), recovery of ferrous (Fe) and non-ferrous (non-Fe) metals and percentage of total MSW-IBA utilised.

Generation and utilisation of IBA										
Country	Data Year	Total TT	IBA Produced		Metal Recovery kt				% Utilised	Method of utilisation
		kt	kt	% $_{MSW}$	Fe	Non-Fe	Total	%IBA		
Germany	**2010**	**19,979**	**5,000**	**25%**	**400**	**50**	**450**	**9%**	-	**Road construction, noise protection walls and other technical applications, recovery on landfills (ramps, shaping)**
France	2008	13,000	2,700	21%	-	-	-	-	80%	80% recovery operations (e.g. road construction), 17% landfills, 3% others
UK	**2015**	-	**1,340**		-	-	-	-	**87%**	-
Italy	2013	5,400	963	18%	n.a.	n.a.	0	0%	71%	Recovery
Netherlands	**2013**	**7,480**	**1,700**	**23%**	**127**	**53**	**180**	**11%**	**100%**	**Road construction, recovery on landfill sites (as construction layer)**
Denmark	2008	3,590	631	18%	-	-	-	-	99%	Recycled (road construction, harbours etc.)
Spain	**2009**	**2,200**	**349**	**16%**	-	-	-	-	-	**Landfill use (ridge, regularization, etc), road construction, cement production**
Sweden	2014	5,698	954	17%	51	17	67	7%	~100%	Predominantly construction on landfill sites
Belgium	**2014**	**2,643**	**500**	**19%**	**36**	**5**	**40**	**8%**	-	**Use of granulates as secondary building material**
Austria	2008	-	358		-	-	-	-	0%	100% landfill (company level)
Poland	**2010**	**40**	**10**	**25%**	-	-	-	-	-	**Block fabrication**
Finland	2014	1,200	223	19%	7%	1.5-4.8%	-	~10%	42%	Road construction & similar, landfill construction, concrete industry
Portugal	**2014**	**1,050**	**187**	**18%**	-	-	**12**	**7%**	**77%**	**Stocks for civil works (25%), landfill cover cells (45%), metals recovery (7%) Landfill (23%)**
Czech Rep.	2014	640	165	26%	8	-	8	5.1%	0%	100% landfill
Hungary	**2014**	**378**	**77**	**20%**	**0.012***		**0**	**0%**	-	**Landfill**
Ireland	2014	229	33	15%	7	0	7	21%	-	Landfill - used for capping
Luxembourg	**2014**	**152**	**26**	**17%**	**2**	**1**	**2**	**9%**	-	**Road construction**

Data on IBA production and utilisation from CEWEP Country Reports available from: www.cewep.eu/information/data/country-reports/index.html, except for the UK which is based on Waste Transfers (incineration of non-hazardous waste) listed in the 2015 Pollution Inventory (available at https://data.gov.uk/dataset/pollution-inventory)
***Metal recovery for Hungary reported in Mt**
Note that use on landfill sites may have been listed as landfill by some countries and recovery by others, leading to some inconsistency in reported recovery rates. Likewise, metal recovery treated as separate item by some countries.

Second, based on the available data presented in Table 17, the mass of MSW-IBA produced is 15-26% of the amount of incinerated waste (median 19%, weighted average 21%), giving a mass reduction on the order of 80±5%. Thus, if it is assumed that total MSW generation remained relatively constant at 2015 levels, an incineration rate of 42±5% would produce ca. 20±6 Mt of MSW-IBA, which would equate to 8±2% of the mass of generated MSW.

The analysis above clearly illustrates that if all of the MSW-IBA generated were to be landfilled, then member states would be at risk of using or exceeding (if more stringent diversion targets are adopted in the future, as discussed in Section 2.5.2) their entire landfill allowance. Furthermore, incinerating such a large proportion of MSW would also put the 2035 65% material recovery target (Table 3; Section 2.5.2) out of reach, unless a significant fraction of the MSW-IBA were able to be recovered. Thus, while the increased use of incineration may be seen as a solution to achieve increased landfill diversion, widespread uptake may lead to lock-in.

With capital costs up to €180 million and operating contracts exceeding 25 years (Nixon et al., 2013) there is a significant chance that incineration facilities commissioned in the near future will be at risk of technological lock-in. Here, local authorities are committed to supplying contracted quantities of waste over decades, regardless of changes in waste composition, volumes and policy (Schneider and Ragossnig, 2015). This risk could be exacerbated further if EU waste policy were to include more stringent waste targets, and/or to introduce specific limits, bans, or taxes for waste managed through incineration (as mentioned within the CEP trilogue discussions; Figure 10 in Section 2.5.2).

There are also more fundamental implications for the transition to the circular economy. Where the circular economy seeks to maintain and recirculate materials and resources, incineration effectively destroys them, albeit alongside the generation of energy. Furthermore, at present, incineration of MSW diverts recyclable materials with high calorific value (e.g. plastics and paper / card) away from material recovery pathways. Indeed, Schneider and Ragossnig (2015) recognise that the recovery of plastic wastes is largely realised through thermal processing, where reasons for this include complex material composition, inadequate source separation, a lack of automated sorting equipment, and the low cost of waste plastics relative to fossil fuels.

While the EC has acknowledged that increased waste-to-energy capacity may jeopardise recycling and thereby undermine the waste hierarchy (Malinauskaite et al., 2017), the CEP did not introduce any outright bans or place explicit limits on incineration (Table 3, Section 2.5.2). Instead, member states may elect to introduce incineration charges and the EC advises that the risk of “stranded assets” is taken into account in investment plans, highlighting the need to consider feedstock availability over the lifespan of new installations without neglecting separate collection and recycling obligations (Malinauskaite et al., 2017; EC, 2017). Thus, notwithstanding the pressure to limit incineration in order to achieve recovery targets (and aid the transition to the circular economy), the incineration of MSW within the EU is set to continue, and seems likely to increase, at least in the short term.

5.3 Recovery and Utilisation of MSW-IBA as a secondary material.

Given the context of continued high (and likely increasing) incineration rates, it is imperative that maximum value is extracted from the MSW-IBA produced, both to increase material recovery rates and to maximise diversion from landfill. Here, extraction of value is considered through currently established routes; metal recovery and utilisation as a secondary aggregate.

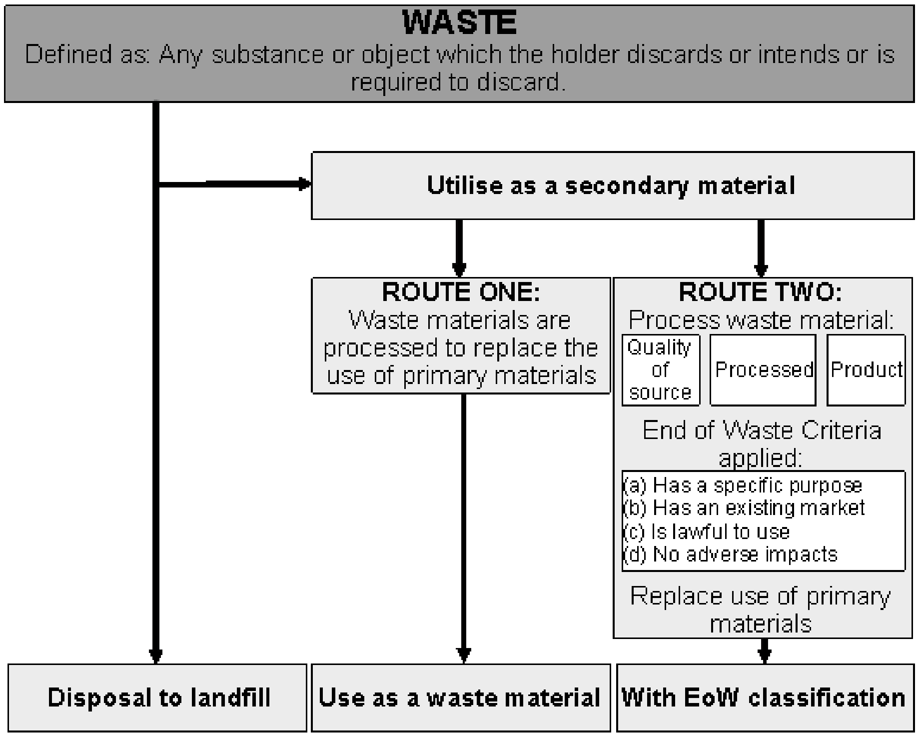
5.3.1 Recovery of metals from MSW-IBA

Based on the somewhat limited available data from the CEWEP Country Reports (Table 11, Section 3.4.2), the recovery of metals from MSW-IBA in the EU is highly variable, ranging from 0-21% of the mass of MSW-IBA, with a median and weighted average of 8%. What remains unclear is the extent to which metal recovery is implemented across the industry, and whether or not advanced recovery techniques are utilised, with no reported data (at country level) for many member states. Given the economic value of metals, plus their contribution to materials recovery targets due to their recovery representing a closed-loop recycling pathway, maximising recovery should be a clear priority.

5.3.2 Routes to utilisation for MSW-IBA

Figure 20 presents the potential routes to utilisation for MSW-IBA (as a waste material or a non-waste in accordance with EoW criteria) and the impact each route has on landfill diversion and recycling targets when compared to disposal to landfill.

Under Route 1, secondary materials maintain the status of a waste. As such, the utilisation, transport and continued monitoring of MSW-IBA must comply with relevant waste legislation, be shown to have no adverse environmental effects and adhere to restrictions and pre-treatment conditions prompted by relevant national legislation (ISWA, 2006; Kuo et al., 2013; Lancellotti et al., 2013; Van Gerven et al., 2005; van der Sloot et al., 2001). Utilisation of secondary materials through Route 1 contributes to landfill diversion but does not contribute to material recovery, instead aligning with the definition of ‘other recovery’ (as defined in Table 4, Section 2.5.2).



REGULATIONS			
Waste regulations			
- Tracking	✓	✓	-
Product regulations			
- Consumer rules	-	-	✓
- REACH	-	-	✓
- Import / export	-	-	✓
- Free trade (in single market)	-	-	✓

CONTRIBUTION TO CEP TARGETS			
Landfill Diversion	-	✓	✓
Material Recovery	-	-	✓
Other Recovery	-	✓	-

Figure 20: Routes to utilisation of MSW-IBA as a secondary material. Alignment with regulations and contribution to targets within the Circular Economy Package (CEP) also shown.

Alternatively, if a secondary material, or a subsequent product, can be shown to adhere to the four qualifying criteria for EoW (Table 5; Section 2.5.4) it can be utilised via Route 2 (Figure 20). Depending on the quality of the source material (waste stream) and level of processing required, EoW status can be defined at different stages. For high quality waste materials that require minimal processing, EoW can be defined at 'quality of source'. For lower quality materials such as MSW-IBA, achieving EoW will require either processing to meet quality levels equivalent to that of primary materials, or being processed into a recognisable and marketable product. To date, the EC have laid down EoW for three priority waste streams. It is noted that the onus to develop EoW for other waste streams has now been placed with member states. After successful application of EoW criteria, a secondary (waste) material is classified as a 'non-waste', removing the need to apply waste regulations. Instead, the material is subject to product regulations, REACH (if appropriate) and import / export regulations. Effectively treating secondary materials in the same fashion as primary materials acts to improve user perception and promote the development of secondary material markets. Within the EU, the material would also be subject to free trade (within the internal market), and thus, in theory, overcoming barriers between member states due to the lack of harmonisation (e.g. of waste definitions) (Delgado et al., 2009). In terms of contribution to the CEP, achieving non-waste status through EoW criteria allows the material to be counted towards material recovery as well as landfill diversion targets (EC, 2008).

5.3.3 Current utilisation of MSW-IBA in the EU

Within the EU, utilisation of MSW-IBA has become commonplace within the construction industry, following Route 1 (Figure 20). Specific applications include use in cement production, as sub-base in road construction, in other civil engineering projects, and as landfill cover (CEWEP, 2010 a, b, 2011, 2013 a, b, 2016 a-c, ESA, 2016, Table 17). The extent of utilisation is primarily influenced by incentives, such as landfill taxes which encourage utilisation in lieu of disposal, in combination with market conditions which dictate the quantities and quality of MSW-IBA required in the construction sector (Villanueva et al., 2006; WRAP, 2006).

While the utilisation of MSW-IBA as a secondary material can contribute to landfill diversion targets, it cannot contribute to material recovery targets while it remains a waste material. Therefore, it may be worth considering the use of EoW (which the EU introduced to address such issues; Section 2.5.4) for the utilisation of MSW-IBA as a secondary material.

5.3.4 Potential role of EoW status for MSW-IBA

Despite this widespread use of MSW-IBA, to date no EoW criteria have been established for its use as a secondary material, either centrally (by the EC) or by any member states. Indeed, while Denmark and the UK have considered developing EoW for MSW-IBA, both countries concluded that it would be inappropriate (in unbound applications) due to environmental risks (Villanueva et al., 2006; EA, 2015; S. Hornby, EA: Personal communication). Specific concerns relate to traceability, where EoW status would remove the requirement to monitor and map the origin and destination of MSW-IBA, which is required under Route 1. This change in requirement has the potential to undermine environmental protection, e.g. risks to groundwater from leaching (Villanueva et al., 2006). However, for certain bound applications, where the end use would be a 'product', EoW may be deemed appropriate (S. Hornby, EA: Personal communication).

While the Danish study acknowledged that EoW status could ease administrative and export burdens, it also highlighted that due to its low financial value, MSW-IBA tends to be used locally, thereby adhering to the proximity principle advocated by the WFD. As such, unconstrained export is not necessarily required (Villanueva et al., 2006). Indeed, both Denmark and the UK use incineration to treat a large proportion of MSW (approximately a half and a third, respectively) and achieve high utilisation rates for the MSW-IBA produced (98% and 87%, respectively) without the use of EoW criteria.

Nonetheless, EoW may have a future role to play. As illustrated in Figure 20, application of EoW may encourage future MSW-IBA utilisation by making it more attractive to potential end users (through removal of waste regulation) and by contributing to material recovery targets. Furthermore, as the amount of waste landfilled declines, in response to both waste prevention initiatives and increased landfill diversion targets, the capacity to utilise MSW-IBA in backfilling operations will diminish. Another point to consider is changes to waste generation. Member states, in accordance the WFD, are obligated to establish waste prevention plans. With no quantitative targets for waste prevention currently set, a conservative approach might assume that MSW generation stays roughly constant. In which case, concerted efforts across the EU to meet landfill diversion targets would see the total amount of MSW sent to landfill decrease to around two fifths of the current capacity (constant MSW generation with a decrease in landfill from 26% to 10%). If incineration is employed as a key (although non-optimal) mechanism to achieve landfill diversion, then alternative uses for MSW-IBA will be required. As such, it is important to explore the potential of other sectors, particularly the construction industry, to absorb additional MSW-IBA in light of potential future generation trends. Furthermore, as discussed above, it would also be beneficial if these alternative uses could be counted towards material recovery targets, which at present would require EoW status.

5.4 Chapter summary

This chapter concludes that incineration has been utilised successfully by some northern EU countries to divert waste away from landfill. It is therefore probable that the use of incineration will continue to increase as member states look to divert more waste away from landfill in light of stringent waste-related targets. However, this use of incineration has the potential to divert feedstock (particularly waste plastics) away from recycling and reuse processes, and therefore may limit increased recycling / reuse, thus creating a potential barrier to the circular economy. Furthermore, due to high capital costs and long contract lengths, the use of incineration could be at risk of technological lock-in. To overcome this, new investments and schemes that involve incineration should take precautions to ensure a guaranteed source of feedstock that does not hamper the ability of local authorities, or indeed, national governments to implement advanced recycling / reuse processes in the future.

That being said, incineration has a role to play as a bridging technology in the transition to the circular economy. As well as producing energy, residual materials such as MSW-IBA are a potential source of secondary materials, where utilisation is already commonplace in many member states. In addition, the application of EoW criteria to incineration residues would allow them to contribute towards recycling targets. Thus, current future targets (i.e. those set by the CEP) could potentially be achieved through a combination of increased incineration and material recovery from MSW-IBA. However, this would promote down-cycling, where, with the exception of metals, recyclable materials will be incinerated (producing energy) to produce the MSW-IBA to utilise as a secondary material under EoW classification. Furthermore, this replicates issues concerning the use of incineration, where focus on short-term targets potentially leads to technological lock-in, and thus creates a barrier to the future implementation of more advanced strategies. To overcome these barriers, mechanisms should prioritise closed-loop recycling, where material recovery achieved through open-loop strategies does not contribute to materials recovery (even with EoW classification) or that it is subject to different targets, where a distinction is made between closed- and open-loop recycling within EU definitions and targets.

CHAPTER 6: Unintended consequences of secondary legislation.

This chapter presents an example of where existing waste and resource management policy is limited in implementation. It examines potential barriers within existing policy and practice that may limit the ability to transition to a circular economy (RQ4; Section 2.6, pg. 81).

This chapter has been published in the peer-reviewed journal, Resources, Conservation and Recycling (see Appendix 3: Fletcher et al., 2018*).*

6.1 Introduction and Chapter outline

Increasing attention is being paid to the use of policy instruments in promoting progressive waste management and supporting the transition to a circular economy. To be effective in this context, instruments must be balanced, providing the correct amount of sanction and incentive to ensure environmental protection, enhance resource recovery, and promote innovation and investment in beneficial technologies.

Focusing on the UK LFT, and adopting a stakeholder-oriented approach, this chapter presents a case study illustrating how ineffective implementation of secondary legislation can have unintended consequences on achieving the aims of primary legislation. Specifically, it examines how the introduction of the QFO (Figure 12 in Section 2.5.7), a statutory instrument used to classify waste, has impacted on stakeholders. Drawing on the results of a stakeholder opinion survey, it examines how the QFO may disincentivise material recovery and thereby limit landfill diversion. In particular, consideration is given to potential modifications that would ensure sufficient environmental protection while enhancing the economic viability of waste processing. Stakeholder views on the design and implementation of the QFO are also presented. Finally, this chapter highlights the identified barriers to material recovery and landfill diversion and suggests potential policy developments to address these.

6.2 Survey responses

6.2.1 Respondent profile

Table 18 presents a breakdown of respondents categorised by organisation type and connection to the LOI testing regime, where Group 1 respondents had a direct connection to the production and disposal of fines, while Group 2 respondents had an indirect connection, either providing auxiliary services or engaged in research or policy development and implementation.

Table 18: Respondent profile categorised according to their connection to the management of fines.

Group 1: Direct connection (n=27)	Group 2: Indirect connection (n=17)
Production and disposal of fines	*Policy development & regulation, auxiliary services, research.*
Waste processing (16) **Landfill operation (5)** **Internal policy compliance (6)**	**Policy development & regulation (4)** **Waste consultancy (4)** **Test provider (6)** **Waste machinery supplier (1)** **Academic research (2)**

Of those respondents who provided their job title (30; 68%), all held managerial or professional positions according to the National Statistics Socio-Economic Classification (NS-SEC) occupation coding tool (ONS, 2010), with the majority (21) being in NS-SEC analytic Class 1 (higher managerial, administrative and professional occupations) and the remainder (9) being in Class 2 (lower managerial, administrative and professional occupations).

Overall, the respondent profile demonstrates that expert opinion from within the waste industry and associated sectors contributed to the survey, indicating good representation for the results.

In the survey, 22 respondents provided at least one ‘don’t know’ or ‘N/A’ response to a closed question. In these cases, all ‘don’t know’ and the majority of ‘N/A’ responses were considered to reflect either a genuine lack of knowledge on the subject, and/or cases where the topic did not apply to the respondent and were excluded. However, ‘N/A’ responses regarding the impact of the LOI testing regime on resource requirements were retained and treated as equivalent to a neutral response.

6.2.2 Workplace resource requirements

Respondents were asked to identify whether the introduction of the LOI testing regime had impacted resource requirements across the workplace (Table 19).

Table 19: Respondent opinion regarding the impact of the LOI testing regime on workplace resource requirements. Significant differences in responses between groups are highlighted.

	All Respondents					Group 1: Direct Connection					Group 2: Indirect Connection					Chi-squared test		
	Large increase	Small increase	Neutral	Small decrease	Large decrease	Large increase	Small increase	Neutral	Small decrease	Large decrease	Large increase	Small increase	Neutral	Small decrease	Large decrease	Group 1 v Group 2		
Workplace Aspect	**#** *(%)*	**#** *(%)*	**#** *(%)*	**#** *(%)*	**#** *(%)*	**#** *(%)*	**#** *(%)*	**#** *(%)*	**#** *(%)*	**#** *(%)*	**#** *(%)*	**#** *(%)*	**#** *(%)*	**#** *(%)*	**#** *(%)*	X^2	df	P-value
Time allocation	6 *14%*	23 *52%*	15 *34%*	0 *0%*	0 *0%*	5 *19%*	18 *67%*	4 *15%*	0 *0%*	0 *0%*	1 *6%*	5 *29%*	11 *65%*	0 *0%*	0 *0%*	12	2	**0.003**
Paperwork	5 *11%*	20 *45%*	19 *43%*	0 *0%*	0 *0%*	5 *19%*	18 *67%*	4 *15%*	0 *0%*	0 *0%*	0 *0%*	2 *12%*	15 *88%*	0 *0%*	0 *0%*	23	2	**0**
Capital expenditure	7 *17%*	9 *21%*	26 *62%*	0 *0%*	0 *0%*	6 *24%*	8 *32%*	11 *44%*	0 *0%*	0 *0%*	1 *6%*	1 *6%*	15 *88%*	0 *0%*	0 *0%*	7	2	0.27
Operational costs	8 *20%*	6 *15%*	27 *66%*	0 *0%*	0 *0%*	6 *25%*	6 *25%*	12 *50%*	0 *0%*	0 *0%*	2 *12%*	0 *0%*	15 *88%*	0 *0%*	0 *0%*	7	2	**0.025**
Staff numbers	1 *2%*	5 *12%*	37 *86%*	0 *0%*	0 *0%*	1 *4%*	4 *15%*	21 *18%*	0 *0%*	0 *0%*	0 *0%*	1 *6%*	16 *94%*	0 *0%*	0 *0%*	2	2	0.435
Maximum impact for any aspect	11 *30%*	18 *49%*	8 *22%*	0 *0%*	0 *0%*	9 *36%*	14 *56%*	2 *8%*	0 *0%*	0 *0%*	2 *17%*	4 *33%*	6 *50%*	0 *0%*	0 *0%*	8	2	**0.014**

Two-thirds of respondents reported some increase in resource requirements when the LOI testing regime was introduced, where the most frequently cited were an increased time requirement and paperwork burden. Group 1 were significantly more impacted than Group 2, reflecting their direct engagement in the management of fines.

Around two-fifths of respondents reported an increase in financial resource requirements, including capital expenditure and / or operational costs. One respondent who identified a neutral impact on capital expenditure noted that it might be required in the future, but *"until the problems relating to variability and accuracy of testing can be overcome, the type and level of expenditure cannot be determined."*

While, six respondents reported an increase in staff requirements, one respondent highlighted a potential negative impact on future employment. Here, the 'huge' increase in operational expenditure was leading a private waste management company to evaluate the financial viability of their sorting stations, where the absence of tax savings in combination with the low value of separated materials results could lead to the plant becoming redundant.

While overall resource requirements have not been hugely impacted by the introduction of the QFO, uncertainty created by the regulation could be seen as a barrier to future investment. This perceived barrier to investment may limit the ability of the UK to continue to increase landfill diversion rates due to a decreased appetite to invest in new technology. A lack of new investment coupled with the risk of plant closure, due to financial unviability, could hamper further diversion efforts by reducing advanced waste processing capacity in the UK.

6.2.3 The 10% LOI threshold

A series of questions explored respondents' views regarding the 10% LOI limit, set as a threshold between the low and standard tax rates and introduced by the QFO. Respondents were first asked whether they considered the 10% LOI limit to be appropriate in representing the attributes of a qualifying fine (i.e. non-hazardous and with low GHG and pollution potentials) before being asked their views on four potential modifications to the LOI threshold.

When asked whether they thought the 10% LOI limit appropriately represented the characteristics of an inert waste, less than half (14) of the respondents (n=33) agreed. As shown in Figure 21, differences were found between the groups.

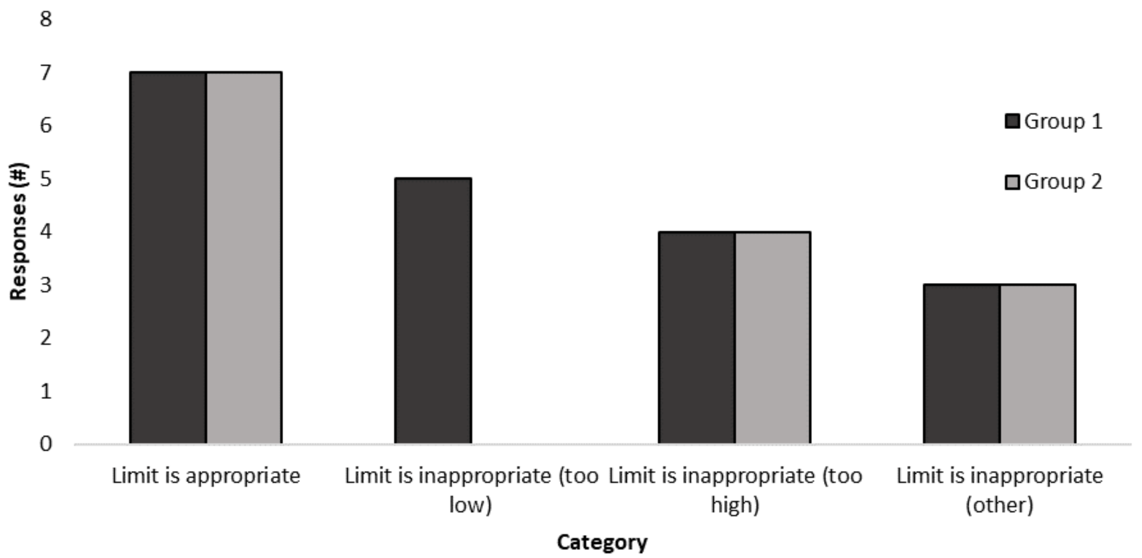


Figure 21: Respondent opinion (by group) concerning appropriateness of 10% LOI limit to represent characteristic of inert waste. Where, Group 1 had a direct connection to the production and disposal of fines, and Group 2 had an indirect connection.

Five respondents (all from Group 1) thought it was too low, citing concerns related to the definition of qualifying fines. Specifically, respondents suggested that materials were being subject to stricter limitations because they had been processed mechanically. For example, material that would automatically be classed as inert, such as sub-soil, can fail the current LOI test. If this material were to be disposed of without being processed mechanically, it would only have to adhere to the QMO and therefore receive an inert classification automatically (Group 1 qualifying material). On the other hand, if it were to be mechanically processed to recover certain materials the residual material would be classified as "fines", and therefore subject to the QFO where the LOI limit would apply.

Eight respondents (from both groups) thought it was too high, noting that fines with 10% LOI "can still generate significant amounts of GHG". Of the six respondents who cited other reasons, half highlighted that it focused solely on GHG emissions taking no account of other factors that influence toxicity or odour potential. For example, one respondent noted;

> *"There needs to be an assessment with regard to the odour potential of such wastes that contain sulphate. The ignition loss is only one aspect, they need to assess long-term gas release and biodegradability […]." (R&D Manager, Private waste management company)*

Other respondents considered the 10% LOI limit to be inappropriate as it appeared to penalise recycling efforts, benefitted fraudsters, and focused on revenue generation. In associated comments, there was a consensus between the respondents that any tax paid on fines should reflect its pollution potential. Several respondents identified that by treating waste, the resultant fines are completely different to the raw, untreated waste, but if they do not achieve the 10% or lower LOI, they are charged the same tax rate. This was viewed as punitive, with respondents highlighting that it fails to reflect the efforts made by the operators to improve waste treatment practices:

> *"It is defeating recycling, recovery and making handling waste too risky for business to invest in, the tax is not doing as intended, its intention was to divert waste from landfill by making it too expensive, it is now making it too expensive to sort as […] you could be left with lots of weight that still due to LOI or chemical*

> *makeup (the fines tend to concentrate contamination) now fail for low rate, so nothing in sorting and recovery is achieved. Companies will simply take out process costs and risks, and landfill." (Director, Private waste management company)*

Respondents' views on four potential modifications to the 10% LOI threshold are presented in Figure 20A. Proposals to either increase or decrease the current threshold were not widely supported, with around four-fifths of respondents giving a neutral or negative response. Not unexpectedly, support for these proposals mirrored views on the appropriateness of the threshold, with those who considered it to be too low or too high favouring an increase or decrease respectively.

Table 20: Respondent opinion regarding LOI limit and testing frequency. Significant differences in responses between groups are highlighted.

	All Respondents					Group 1: Direct Connection					Group 2: Indirect Connection					**Chi-squared test** Group 1 vs Group 2		
	Strongly agree	Agree	Neutral	Disagree	Strongly disagree	Strongly agree	Agree	Neutral	Disagree	Strongly disagree	Strongly agree	Agree	Neutral	Disagree	Strongly disagree			
	# (%)	# (%)	# (%)	# (%)	# (%)	# (%)	# (%)	# (%)	# (%)	# (%)	# (%)	# (%)	# (%)	# (%)	# (%)	X^2	df	P-value
A. Views on potential modifications to the 10% LOI limit																		
Increase the LOI limit	4 (11%)	3 (8%)	15 (42%)	9 (25%)	5 (14%)	4 (27%)	3 (20%)	5 (33%)	3 (20%)	0 (0%)	0 (0%)	0 (0%)	10 (48%)	6 (29%)	5 (24%)	6	4	0.203
Decrease the LOI limit	4 (11%)	3 (8%)	13 (35%)	9 (24%)	8 (22%)	2 (11%)	1 (5%)	2 (11%)	7 (37%)	7 (37%)	2 (11%)	2 (11%)	11 (61%)	2 (11%)	1 (6%)	9.4	4	0.053
One additional tax band	3 (8%)	16 (43%)	6 (16%)	6 (16%)	6 (16%)	1 (6%)	11 (61%)	3 (17%)	2 (11%)	1 (6%)	2 (11%)	5 (26%)	3 (16%)	4 (21%)	5 (26%)	7.4	4	0.117
Multiple additional tax bands	8 (22%)	4 (11%)	11 (30%)	8 (22%)	6 (16%)	7 (39%)	4 (22%)	4 (22%)	2 (11%)	1 (6%)	1 (5%)	0 (0%)	7 (37%)	6 (32%)	5 (26%)	10	4	**0.037**
B. Views on the current method to determine test frequency																		
The test regime is clear	1 (3%)	16 (41%)	11 (28%)	8 (21%)	3 (8%)	1 (5%)	7 (33%)	6 (29%)	5 (24%)	2 (10%)	0 (0%)	9 (50%)	5 (28%)	3 (17%)	1 (6%)	1	4	0.912
The test regime is fair	1 (3%)	11 (29%)	13 (34%)	6 (16%)	7 (18%)	1 (5%)	3 (14%)	7 (33%)	5 (24%)	5 (24%)	0 (0%)	8 (47%)	6 (35%)	1 (6%)	2 (12%)	4.5	4	0.34
C. Views on potential modifications to determination of test frequency																		
Include spike allowance	6 (15%)	25 (64%)	4 (10%)	3 (8%)	1 (3%)	5 (29%)	10 (59%)	2 (12%)	0 (0%)	0 (0%)	1 (5%)	15 (68%)	2 (9%)	3 (14%)	1 (5%)	12	4	**0.019**
Fixed number of tests	4 (11%)	6 (16%)	11 (30%)	14 (38%)	2 (5%)	3 (16%)	5 (26%)	5 (26%)	5 (26%)	1 (5%)	1 (6%)	1 (6%)	6 (33%)	9 (50%)	1 (6%)	2	4	0.734
Increase number of risk categories	1 (3%)	6 (16%)	12 (32%)	15 (41%)	3 (8%)	1 (6%)	4 (25%)	6 (38%)	5 (31%)	0 (0%)	0 (0%)	2 (10%)	6 (29%)	10 (48%)	3 (14%)	3	4	0.559
Decrease number of risk categories	0 (0%)	3 (8%)	15 (41%)	15 (41%)	4 (11%)	0 (11%)	2 (5%)	6 (11%)	7 (37%)	1 (37%)	0 (11%)	1 (11%)	9 (61%)	8 (11%)	3 (6%)	1	3	0.796

However, proposals to replace the single threshold with banding received a mixed response. Around half of the respondents supported the addition of one extra band, with around a third opposed, and a sixth neutral. Overall support for multiple bands was somewhat lower, with a broadly even split between supportive, opposing, and neutral responses. However, there were significant differences between the groups, where Group 1 supported multiple bands and Group 2 opposed.

This difference in opinion may reflect the different perspectives of the two groups, where Group 1 viewed banding as a means of removing the perceived disincentives to material recovery. Here, arguing that banding would strengthen the economic viability of processing operations, and with one respondent suggesting a sliding tax scale (e.g. an increase in tax rate of the order of £5 for each percentage point above the threshold) would be a preferred solution:

> *"A lot of problems caused by the 10% fixed limit could be alleviated if there was a sliding scale of tax linked to the LOI. So for example you might have land fill tax set at £5 for a LOI of 10% or less, with increases of £5 for each percentage point above the 10% threshold." (Partner, Private management waste company)*

For the most part, Group 2 did not oppose the principle of banding, but held concerns regarding the ability to implement it. Respondents noted that the LOI test is neither precise nor accurate enough to support banding and identified specific issues with the methodology (e.g. missing details regarding vessel size, and depth/surface area of the sample) that would contribute further to a high variation in test results within and between laboratories. Indeed, a number of respondents highlighted that this variation (reported to be around 2%) leads the current regime (under which significant additional cost is incurred if the LOI test result is 0.1% over the threshold) to be perceived as unfair. The respondents suggest that the tax threshold should reflect this (un)reliability, potentially through inclusion of an allowable measurement error.

6.2.4 Frequency of testing

Currently, frequency of testing is dependent on previous test results taking into account consistency of pre-acceptance checks, outcome of visual inspections, and the LOI result from the last and previous 20 tests (See Figure 12 in Section 2.5.7 Point 5b - prescribed testing frequency). Respondents were asked to what extent they agreed that; (1) the test regime is very clear with testing frequency that is easy to determine; and (2) the risk categories used to determine testing frequency are fair (Table 20B).

Around a third of respondents considered the method to be unclear and / or unfair. Concerns were related to the practicability of the test regime due to the size of operations and the time delays between delivery of waste to site and receiving test results. Respondents that strongly disagreed that the risk categories used to determine testing frequency are fair, reported that the regime is unworkable due to the size of operations, that it is open to abuse by rogue traders and it does not address the potential problem of liability between landfill operators and waste producers;

> *"With many sites producing in excess of 500 tonnes per week and an LOI test taking up to three weeks to receive the results this is again unworkable." (Managing Director, Private waste management company)*

One respondent, who agreed that the use of risk categories was fair, also raised a concern regarding rogue traders, indicating that some operators may possibly discard test results to avoid moving into higher risk categories, requiring more frequent testing and therefore cost.

To improve the determination of test frequency, respondents were asked their views on four potential modifications to the current method. The first modification continues to use the established risk categories to determine the number of tests, but an allowance is introduced for spike results. The second modification replaces the risk categories with a set number of tests, which are fixed for all. The final two modifications continue to use risk categories to determine test frequency, but either reduce the number of categories to two or increase them to more than three.

As shown in Table 20C, only the introduction of a spike allowance received wide support, with less than a third of respondents supporting the other suggestions.

Respondents, identified as being involved in internal compliance and external policy implementation, commented that the introduction of a fixed number of tests per year for everyone would be simpler, but would lead to increased overall burden. With the former (respondent identified as internal compliance), noting that that material with a greater pollution potential should be exposed to an increased testing frequency:

> *"Although it may be simpler to have the same testing requirements for everyone, I believe it is appropriate to have risk bandings - if*

waste is from sources that have more potential to be polluting (or present more risks to the environment); I believe it should be under [an] increased testing regime." (Environmental Compliance Manager, Private waste management company)

However, the risk that a prescribed test schedule would be open to abuse (e.g. through the provision of compliant but atypical samples) was also identified, with one respondent noting "huge savings could be made from bad practice".

Proposals to either increase or decrease the number of risk categories received the least support, where respondents highlighted that the use of risk categories (even those established) was unworkable due to the inherent variability of the materials, length of time required to test a sample, and the poor accuracy and precision of the test.

Around four-fifths of respondents supported the introduction of a spike allowance, with stronger support (and no opposition) from Group 1. One opposing respondent from Group 2 noted that the introduction of spike allowances would defeat the object of the LOI testing regime:

"Ignoring spikes would defeat the object as the aim is to incentivise robust processes for achieving outputs that consistently achieve LOI < 10%." (Policy and Technical Lead, Environmental regulator)

However, a respondent from Group 1 that supported the modification, commented that allowance for spike results should be built into a banding system, but notes the need for constraints on allowable spikes:

"I believe some allowance for spike results could be built into the bandings, e.g. if 1 in 10 tests spikes over 10% (by no more than an extra 2%, for example), then it should be reasonable to suggest it is still in the lower risk banding." (Environmental Compliance Manager, Private waste management company)

Using a constrained spike allowance, as suggested above, could negate the risks of ignoring spike results completely and would be more in line with other established methods of classification. For example, to determine hazardous status of a waste material, waste producers must test their output material at least twice a month against sixteen (hazardous) properties before it is moved, disposed of, or recovered (ESA, 2016; EA, 2015). Determined on a 24-sample rolling basis and based on chemical composition, the material would be deemed hazardous if more than five properties exceed the relevant limit or if one property limit is exceeded four times or more (ESA, 2016). This is completed by the waste producer and is used to inform the EWC applied and the overall management of the material (ESA, 2016; EA, 2015).

6.2.5 Support for the implementation of the LOI testing regime.

When asked their views regarding current support for implementation of the LOI testing regime, more than half of the respondents reported that the support was inadequate, with less than a fifth finding the support adequate (Table 21A). Dissatisfaction was higher in Group 1, with a clear majority reporting inadequate support. These respondents perceived a lack of expertise within HMRC regarding the waste industry and waste related taxes, citing the advocacy of a poorly defined test method. Furthermore, some respondents considered that landfilling of waste was effectively "unpoliced", thereby enabling "cowboy operators" (a term used to refer to dishonest or unscrupulous operators) to falsely describe material in order to send it to landfill as inert. To address this issue, one respondent suggested that the HMRC should take the lead in testing more sites to ensure compliance and consistency.

Respondents' views on six potential modifications to enhance the support provided for implementation of the LOI testing regime are presented in Table 21B. First, the respondents were asked whether laboratories used for LOI testing should be standardised and / or accredited. Next respondents were asked whether more support should be made available to interpret the LOI testing regime and if guidance should be simplified. Then respondents were asked whether sampling of fines should be undertaken by an independent accredited third party. Finally, respondents were asked whether HMRC should introduce tax breaks for technology investment or endorse specific processes and/or machinery for the production of qualifying fines.

Table 21: Respondent views regarding current and future support available for implementing the LOI testing regime. Significant differences in responses between groups are highlighted.

	All Respondents					Group 1: Direct Connection					Group 2: Indirect Connection					Chi-squared test Group 1 vs Group 2		
	Strongly agree	Agree	Neutral	Disagree	Strongly disagree	Strongly agree	Agree	Neutral	Disagree	Strongly disagree	Strongly agree	Agree	Neutral	Disagree	Strongly disagree			
	# (%)	# (%)	# (%)	# (%)	# (%)	# (%)	# (%)	# (%)	# (%)	# (%)	# (%)	# (%)	# (%)	# (%)	# (%)	X^2	df	P-value
A. Views on the adequacy of support provide to implement the LOI tetsing regime																		
Adequate support	1	5	9	10	10	1	0	4	7	6	0	5	5	3	4	13.45	4	**0.009**
	3%	*14%*	*26%*	*29%*	*29%*	*6%*	*0%*	*22%*	*39%*	*33%*	*0%*	*29%*	*29%*	*18%*	*24%*			
B. Support for potential modifications to the LOI testing regime to enhance support																		
Laboratory certification	20	19	3	2	0	12	6	3	0	0	8	13	0	2	0	6.539	3	0.088
	45%	*43%*	*7%*	*5%*	*0%*	*57%*	*29%*	*14%*	*0%*	*0%*	*35%*	*57%*	*0%*	*9%*	*0%*			
Provide more support	9	26	4	1	1	6	11	2	0	0	3	15	2	1	1	3.523	4	0.474
	22%	*63%*	*10%*	*2%*	*2%*	*32%*	*58%*	*11%*	*0%*	*0%*	*14%*	*68%*	*9%*	*5%*	*5%*			
Simplify guidance	7	23	7	2	2	4	10	4	0	0	3	13	3	2	0	3.368	3	0.338
	18%	*59%*	*18%*	*5%*	*5%*	*22%*	*56%*	*22%*	*0%*	*0%*	*14%*	*62%*	*14%*	*10%*	*0%*			
Independent sampling	*16*	*13*	*7*	*7*	*0*	*8*	*3*	*5*	*4*	*0*	*8*	*8*	*4*	*3*	*0*	3.041	3	0.385
	37%	*30%*	*16%*	*16%*	*0%*	*40%*	*15%*	*25%*	*20%*	*0%*	*35%*	*35%*	*17%*	*13%*	*0%*			
Tax breaks	*9*	*12*	*4*	*6*	*1*	*8*	*4*	*1*	*4*	*0*	*1*	*5*	*3*	*2*	*1*	7.941	4	0.094
	28%	*38%*	*13%*	*19%*	*3%*	*47%*	*24%*	*6%*	*24%*	*0%*	*7%*	*53%*	*20%*	*13%*	*7%*			
Endorsement	6	9	3	9	8	5	7	2	4	1	1	2	5	5	7	8.863	4	0.065
	17%	*26%*	*9%*	*26%*	*23%*	*26%*	*37%*	*11%*	*21%*	*5%*	*6%*	*13%*	*31%*	*31%*	*44%*			

The majority of respondents agreed that further support from HMRC would be of a benefit. However, one respondent stated that the guidance was clear and that it was the responsibility of the operator to understand and comply with all relevant legislation. Although this is a relevant point, when clarification is needed by waste operators to interpret the order accurately, there is feeling amongst the respondents that support is not available due to poor training and lack of specific knowledge, with one respondent noting that:

> *"HMRC have admitted that they don't have a single officer trained to correctly classify wastes either for environmental or tax purposes." (Managing Director, Private waste management company)*

The majority of respondents agreed that simplified guidance and a simplified process would be helpful. In associated comments, respondents suggested that the LOI testing regime should be absorbed into the pre-acceptance checks to make them less subjective. It is thought that this would alleviate the perceived unfair liability on landfill operators to apply the correct tax rate.

While the cost of landfill tax is ultimately met by the producer of the fines, often the landfill operators are liable for ensuring the correct rate is applied. When an LOI test is not required the pre-acceptance checks questionnaire, transfer note and visual inspection are used to determine rate, and as one respondent commented, this relies heavily on the producer:

> *"The landfill operator has to rely on the information provided to him on a questionnaire, but the reality is that it relies on the transfer station operator [fines producer] being both truthful and able to ensure that his operatives comply with his operating procedures each and every day." (Managing Director, Private waste management company)*

When a LOI test is required, it is the responsibility of the landfill operator to ensure a representative sample is taken and tested in a timely manner. If a sample were to fail, and give an LOI test result above 10%, it is the landfill operator's duty to inform the HMRC, ensure the correct tax is paid for that load and subsequent loads, and review testing frequency and pre-acceptance checks. It has been argued that this creates uncertainty and confusion, with one respondent stating:

"There should be no situation where a load can be accepted by the tip [Landfill operator] thinking the tax will be £2.60 and then at some future point the tax is increased to £82.60. Both the producers of fines and the landfill operators need certainty and clarity. The system at the moment offers only confusion and uncertainty." (Partner, Private waste management company)

Two thirds of respondents supported the introduction of third-party sampling. Respondents who disagreed noted that it would increase costs and timescales. While one respondent insisted that self-sampling was efficient, they also acknowledged that it is open to abuse. Another commented that it would be unnecessary if the fines are taken to accredited/standardised laboratories and the production process is supported with evidence:

"As long as the fines are taken to a standardised/accredited Lab and there is the full flow diagram, photo's etc to support the production process, then there should not be the need for the extra cost burden of independent 3rd part [sic] sampling." (Co-Director, Private waste management company)

LOI test standardisation and laboratory accreditation was the most strongly supported proposal, reflecting the concerns raised throughout the survey regarding the accuracy of the testing regime. Respondents noted this would negate issues concerning margin of error between laboratories and address issues related to the fixing of results. It was also suggested that test providers develop the testing regime so that it addresses concerns relating to accuracy and reliability, where evaluation of the actual margin of error across all (accredited) testing providers could be incorporated into a reframing of the LOI limit (i.e. 10% ± margin of error).

Two thirds of respondents supported the introduction of tax breaks for new technology. While one respondent commented that tax breaks were unnecessary and that reductions in tax liability should finance changing technology, earlier responses from Group 1 highlighted that uncertainty (in producing fines that qualify for the lower rate of tax) can create a barrier to future investment.

Overall, there was a broadly even split between those who supported and those who opposed the approval of specific material recovery processes that produce fines. Here, the majority of Group 1 were supportive, and the majority of Group 2 were opposed. One respondent suggested that HMRC should approve processes in combination with third party sampling, with analysts from independent laboratories employed to take random, unannounced samples:

> *"The regime should be that a producer of waste fines has their process approved by HMRC. The producer then has to pay for analysts from an independent laboratory to take random, unannounced samples. […] The landfill operator can then rely on these samples and any liability for additional landfill tax is the responsibility of the waste producer. […]" (Managing Director, Private waste management company)*

However, another respondent (who strongly disagreed) suggested that the focus should be on how inputs influence fines composition:

> *"Endorsing processes would achieve nothing as controlling inputs to a process is likely to be the most important factor affecting fines composition." (Policy and Regulation Lead, Environmental regulator)*

This suggests that the lack of support for process endorsement may at least partly reflect differing interpretations of what that would entail, as a waste separation process is typically designed for a specific input stream. Nonetheless, the point that inputs exert the primary control on the composition of the resultant fines is valid, and if process endorsement were to be pursued, actual inputs must be taken into account.

6.3 Discussion and recommendations

6.3.1 The QFO may act as a barrier to investment

This research has found that the QFO may act as an unintended barrier to investment in future waste processing, thereby acting counter to the intended goal of the UK LFT to promote landfill diversion and the more recent policy imperative to enhance material recovery. Due to the low value of separated materials, the financial viability of processing can be poor, leading some operators to consider closing existing sorting stations, particularly when anticipated tax savings are not fully realised. Furthermore, uncertainty concerning the accuracy and reliability of the LOI testing regime may negatively impact decisions regarding the type and level of investment required for advanced processing.

Theoretical scenarios under which the QFO may influence landfill diversion are illustrated in Figure 22. In scenario one, active wastes have the potential to achieve inert classification after advanced processing to remove active material. This provides the greatest potential incentive for investment due to benefits arising from the significantly decreased disposal costs (reduced tonnage and tax liability of residual fines), in addition to the value of the separated material (expected to be low). However, this incentive depends on the ability to generate residual fines with 10% LOI or less. In scenario two (removal of inert material from active waste), financial benefits arise only from the reduction in tonnage disposed and the value of the separated material, thus providing a reduced incentive for investment compared to scenario one. In scenario three (removal of active material from inert waste), the financial benefits are further reduced due to the original low disposal costs, providing little to no incentive for advanced processing. In scenario four (removal of inert material from inert waste), there is a strong disincentive for further material recovery due to the risk of residual fines exceeding the 10% LOI limit resulting in significantly increased disposal costs.

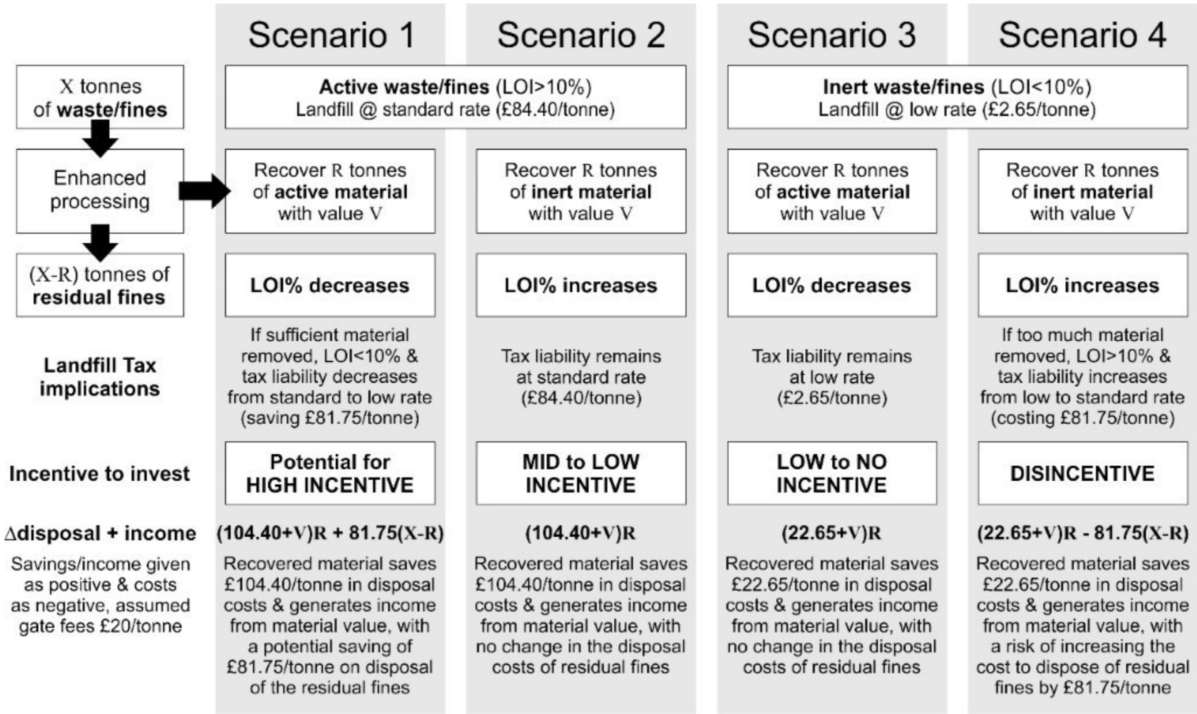


Figure 22: Level of (dis)incentive to invest in advanced processing of fines taking into account current landfill tax implications of both the input waste and the residual fines.

These scenarios clearly illustrate the shortcomings of applying a single threshold between two disparate tax rates at the somewhat arbitrary 10% LOI threshold. Modifying the tax to one based on multiple bands or a sliding scale has the potential to address this issue, strengthening the incentive for advanced processing in all cases except when the LOI of the original material is marginally greater than 10% and the removal of a small amount of active material would currently trigger a substantial saving. Amalgamating the various proposals put forward by respondents suggests some form of gradation in intermediate tax rates between 5% and 20% LOI would incentivise further separation and alleviate industry concerns that the current tax regime is punitive with a greater focus on revenue generation than environmental protection. This could be strengthened by combining taxation with direct incentives for investment, particularly in cases where the projected return is low or negative and could potentially be achieved through recycling tax revenue to provide an enhanced capital allowance on ‘resource efficient technologies’, as is currently available in the UK for a range of energy and water efficient technologies. However, this may lead to greater procedural challenges, where implementation of the current legislation is already limited due to an unsatisfactory level of clarity.

6.3.2 Clarity is needed regarding responsibility for fines classification and LOI testing

A number of issues regarding the implementation of the QFO with respect to the relative responsibilities and liabilities of key stakeholders were raised. This includes the perception that the test regime is vulnerable to abuse and concerns over uncertain costs at time of disposal.

At present, the waste processor is required to correctly describe and classify fines, where it is the responsibility of the landfill operator to verify the description, complete an LOI test if necessary, and ensure the correct tax rate is applied. It was suggested that this leaves the landfill operator vulnerable to unscrupulous waste processors (through provision of an incorrect description), and the system vulnerable to unscrupulous landfill operators (if results are manipulated), where there was a perception that the system is virtually unpoliced, with minimal compliance checks taking place.

In addition, due to the time required to complete an LOI test (up to three weeks) a situation may arise where fines are accepted for disposal as inert and are later reclassified as active. This risk of change in tax liability introduces uncertainty into the business models of waste processors and landfill operators, and with respect to the former may create a barrier to investment. Furthermore, a failed test result would require subsequent loads to be tested, where these may already have been landfilled in the time taken to evaluate the earlier load. Such situations may explain why the current regime has been described as unworkable.

Absorbing the LOI testing regime into pre-acceptance checks could provide a solution and would align it with other established methods of classification such as that introduced to determine hazardous status of a waste (EA, 2015). Employing routine testing where classification is determined on a rolling-basis would provide a greater level of certainty regarding fines classification prior to disposal, with the responsibility of correct classification squarely placed with the producers. Furthermore, it could be argued that this would better represent the fines being produced over time and be more consistent in classification. Overall, this could lead to a more workable scenario for the proposed graduated tax rates as discussed earlier.

6.3.3 The LOI test regime is currently not fit for purpose

Meaningful discussions regarding the operational procedures of the QFO are contingent upon an LOI test regime that is fit for purpose and adequately represents the characteristics of qualifying fines. With regard to the latter point, while the use of LOI as a sole measure of environmental burden was questioned, it is noted that it does reflect a key driver of landfill diversion (GHG emission reduction) and it is the author's view that immediate priority should be given to improving the LOI test regime.

Throughout the survey, respondents repeatedly emphasised that the LOI test is severely limited, being both inaccurate and imprecise. The validity of a standardised test is dependent on the reproducibility of results, both within and between laboratories (Geurts et al., 2016). While LOI is often used in soil analysis due to its simplicity and cost-effectiveness, it is generally considered to provide only a crude indication of organic content where test accuracy is known to be affected not only by the sample clay content, but also by a range of procedural details (Hoogsteen et al., 2015; Wang and Wang., 2011). In addition to the inherent limitations of the test and the failure of the QFO to specify key procedural parameters such as specific times / temperatures within the drying phase (thereby leaving it open to interpretation by different test providers), the method and frequency with which samples are obtained has also been criticised for being open to bias and failing to represent the material being landfilled. These limitations could be mitigated by developing a stringent test regime, with little or no room for interpretation, accrediting test providers, and employing third party independent sampling.

6.4 Chapter summary

For waste policy to be effective, particularly in the context of driving the transition to a circular economy, it should be balanced; providing the correct amount of sanction and incentive to enhance resource recovery while ensuring innovation (and investment in progressive waste management strategies) is not stifled. Employing a stakeholder-oriented approach, this chapter has illustrated an example of unbalanced policy, where secondary legislation (the QFO) introduced to address a specific issue (fines classification) has had an unintended negative impact on the principal aim of the primary legislation (the UK LFT) to increase landfill diversion. Specifically, it was found that the QFO has created a perverse incentive to decrease landfill diversion through limiting the recovery of secondary materials (underpinning principle of the circular economy) and discouraging investment in technology (required for the transition to the circular economy).

While a number of stakeholder dissatisfiers were found to have undermined the implementation of the QFO, most notably the complexity of (and missing details in) the QFO guidance and a perceived lack of support from HMRC, the most critical factors identified were related to policy design. Here, the process for determining the classification of fines and the discontinuity in disposal costs were both identified as major weaknesses with negative impacts on environmental protection, profitability, and investment in technology. These findings highlight both the importance of policy coordination when multiple constraints are present, and the insights that stakeholders can provide (while acknowledging that these will inevitably reflect vested interests) regarding the design and implementation of market-based policy instruments.

With respect to the classification of fines, the current process was found to be open to interpretation and abuse (leading to variation in and misclassification of fines) and was viewed as unworkable and unfair. This arose from a division of responsibility between the producer and the landfill operator, an apparent lack of compliance checks, the time lapse between load delivery/disposal and the receipt of LOI test results. In addition, the LOI test regime is poorly described such that it is open to sampling bias, lacks methodological details and fails to take account of the inherent limitations of LOI testing. With respect to the discontinuity in disposal costs, the single boundary in tax rates at the 10% LOI threshold was not only found to be a blunt instrument for promoting landfill diversion, but one which actively dis-incentivises material recovery. In turn this can lead to a cessation in current separation practices and acts as a barrier to investment in new separation technologies.

To address these issues, the following recommendations are made.

1 Priority must be given to the development of a robust LOI test method with fully defined operational parameters. This should include an assessment of reproducibility within and between testing laboratories in order to determine an appropriate measurement tolerance that can be taken into account when classifying fines for tax purposes.

2 It is recommended that the balance of responsibility for fines classification is shifted to the waste processor, with LOI determined on a rolling basis and incorporated into pre-acceptance checks (similar to hazardous waste classification). Sampling frequency should be based on risk categories that reflect the composition of input wastes, the processes employed, and the consistency of LOI test results, with third-party sampling and/or regular compliance checks to protect the system from abuse.

3 The 10% LOI threshold should be replaced by multiple tax bands or a sliding scale and ideally would be combined with a direct incentive for investment such as an enhanced capital allowance for resource efficient technologies. At a minimum, it is imperative that the current strong disincentive for recovering inert material is redressed.

As a final note, it is emphasised that explicit consideration must be given to the interaction between environment and technology during the policy design process in order to ensure that the continued evolution of waste management policy is effective.

CHAPTER 7: Circular Economy Readiness

This chapter presents the results of a stakeholder workshop that considered the role of the waste and resource management sector in the transition to the circular economy. In particular, it seeks to identify and address existing barriers within the sector that may limit this transition (RQ5; Section 2.6, pg. 82). Specifically, this chapter asks whether the concept of 'readiness' could be usefully employed by the waste and resource management sector to promote the transition toward the circular economy and successfully address barriers (RQ6; Section 2.6, pg. 82).

7.1 Introduction

The identification of financial, structural, operational, attitudinal and technological barriers to the transition to a circular economy highlights the need to develop future-proofing strategies. CCR is an example of a future-proofing strategy that enables the energy sector to address the needs of the current generation, while preparing for increasingly stringent environmental policy (as discussed in Section 2.4.4). An analogy can be drawn between the evolution of the waste and resource management and energy sectors, where both sectors have become increasingly bound by stringent environmental policies, are subject to potentially competing priorities, and are complex socio-technological systems, resistant to change and at the risk of technological lock-in.

To understand the contribution of waste and resource management sector to the circular economy and potential barriers to successful implementation, a stakeholder workshop was held to explore the concept of 'Circular Economy Readiness'.

7.2 Circular Economy Readiness workshop

7.2.1 Contribution of waste and resource management sector to the circular economy.

As an introductory activity, workshop participants were asked to discuss what contribution the waste and resource management sector could make to the circular economy. Workshop participants highlighted the provision and preservation of resources as a key contribution. This corroborates the argument made by Salemdeeb et al. (2016) that the waste and resource management sector has a vital role to play in the transition to the circular economy by maintaining and recirculating resources and materials within supply chains. Furthermore, by implementing a range of tools and strategies, the participants thought that the sector could become enablers of the circular economy by connecting industries and improving stakeholder awareness. In turn, economic, social and environmental benefits could be promoted. This agrees with Jedelhauser and Binder (2018) that advocate the use of soft infrastructure tools such as social tools and institutional regulation alongside hard infrastructure (i.e. technological innovation) in the transition to the circular economy. While the points raised here are valid and align with arguments presented in the literature, for example by Salemdeeb et al., 2016; Soderman et al., 2016; Gregson et al., 2015, etc. (as discussed in Section 2.5.1), due to this activity being used as an ice-breaker and to stimulate initial discussion, they will not be explored any further.

7.2.2 Overcoming existing barriers within the waste and resource management sector to enable the transition to the circular economy.

Table 22 presents a synthesis of the workshop outputs from the three groups. The identified barriers and suggested solutions within the five themes (Financial, Structural, Operational, Technological and Attitudinal) are given in more detail below and discussed in light of the literature.

Table 22: Barriers identified within the workshop participants to the circular economy, and suggested solutions

BARRIERS	SOLUTIONS
Financial	
Budget constraints	
- large initial investments	-
- ongoing costs	
Limits to existing financial incentives	-
Unclear responsibility	Extended Producer Responsibility
- who should pay	
- venture capital vs. public contributions	
Uncompetitive secondary material markets	Better regulation that promotes the utilisation of secondary or recycled materials and is aligned with economic benefits
- external competition with primary markets	
- internal volatility	
Continued focus on economic value	
Structural	
Data constraints	Standardise and promote consistent use of data collection tools
- limited availability of data (especially historical data)	
- data available can be poor quality	
Reliance on existing system structures	Develop tools to promote innovative business models
- based on traditional business models	
- promotes the selling of goods	
- reluctance to enable repair and reuse to reduce lost	
- full value chain not taken into account	
- landfill and incineration continue to be viable options in planning	
Limited independent certification [/assessment?]	
- lack of standards	-
- limited monitoring and performance testing	

Operational	
Access to (waste) materials	-
- often low quality and over a large area	
- mixed content found in historic landfills	
Contractual obligations	Inclusion of flexibility or option within new contracts that can be utilised when the conditions change.
- often lengthy	
- changes are difficult unless options are written in at the start	
Unsupportive legislative environment	Standardisation and unification of standards, regulations and systems.
- divergent policies and legislation (national, international)	
- imprecise laws and regulation (local, national)	
- divergent management schemes (local)	
Lack of quality knowledge exchange	
- poor dissemination of good practice within and outside the sector	
- poor transparency and accountability of information within the sector	
Technological	
Issues related to technology used in resource management	-
- long lifespan	
- divergent availability of appropriate technology	
Issues relating to innovative materials	Apply eco-design principles in development stage
- poor reusability and recyclability of novel materials	
- poor application of biodegradability	
- questionable quality of products with recycled content	
Attitudinal	
Poor consumer behaviour	Use of role models to deprioritise fast fashion
- willing victims of consumerism (fast fashion)	Stimulate de-hoarding
- hoarding (legacy wastes from previous decades)	Increase awareness of consumption and consumerism.
- wasteful culture	
Limited awareness	Diversify awareness campaign across demographic groups
- reuse only attractive to some (eco-warriors or those on a limited income)	
- poor awareness of prevention activities	
- lack of understanding regarding CE concept and its implications	Education at all levels
- varied engagement with recycling schemes leading to contamination and poor quality inputs	
Poor links between research, innovation, education and business	Create stronger links between sectors
- lack of social inclusion	

Financial barriers found in the waste and resource management sector include issues related to investment in new processes, uncertainty regarding market viability, limits to current financial (dis)incentives to promote the use of recycled / recovered materials and costs related to the ongoing implementation of strategies. Furthermore, specific issues related to secondary materials markets were highlighted that may limit the use of recycled materials in the production chain, particularly when compared to virgin materials (which are often more economical); an issue also highlighted by the CEP (EC, 2016a). The CEP while reiterating the waste hierarchy and revising waste-related targets has also introduced new priorities that advocate resource efficiency and a focus on full product life-cycle thinking. The new priorities also encourage industrial symbiosis and the development of secondary materials markets (EC, 2016a; Pomberger et al., 2017). However, the success of such strategies continues to be dependent on cost-effectiveness, where economic and territorial policies modify conditions for profitability (Moreau et al., 2017). Indeed, a potential conflict between private (venture capital) and public funding was noted by the workshop participants, where the responsibility for funding waste and resource management was questioned, i.e. should it lay with the consumers, the government or business and industry.

To overcome these barriers, better regulation was suggested where the expectation to use recycled or secondary materials are aligned with economic benefits, i.e. incentives and / or tax breaks. For such regulation to be successful, however, strategies would need to go beyond economic viability of material recycling, so that social and institutional dimensions are included (Moreau et al., 2017). Furthermore, the management of existing anthropogenic materials stocks would need to be addressed. The workshop participants highlighted Extended Producer Responsibility (EPR) as a means to fund waste and resource management. EPR emerged in Sweden and Germany during the 1990's and has since been adopted by the EU, and in basic terms, it places responsibility for end-of-life management with the producer (Lifset et al., 2013). It is thought that by stimulating the design and distribution of environmentally-friendly products, EPR could address several interrelated goals such as leveraging private sector expertise, internalising the costs of waste and resource management and shifting the financial burden of waste management away from public finances (Brouillat and Oltra, 2012; Lifset et al., 2013). Current implementation of EPR has been restricted to the following waste streams; end-of-life vehicles, electrical and electronic equipment, packaging, batteries, paints and unspent pharmaceuticals. Feedback from implementation has found that rather than influencing product design, the primary achievement of EPR has been to fund and expand infrastructure for post-consumer recycling (Lifset et al., 2013). Deviating away from the theoretical optimal policy, implementation of policy instruments such as EPR can be influenced by lobbying powers of stakeholders and other externalities (Atasu and Van Wassenhove, 2012). Negative influences were also highlighted by the workshop participants, whom agreed that while measures such as EPR could be effective, they could also be difficult to implement due to an existing resistance to change within environmental legislation and strong lobbying of associated industries.

The structural barriers highlighted by the workshop participants included the lack of good quality data, a continued reliance on traditional system structures and limited external validation. It was agreed that data within the waste and resource management sector is generally poor. Where ineffective mechanisms to collect and store the data (manually, electronically, etc), along with poor accessibility and dissemination, affected the quality of data available. Participants mirror the concerns of Niska and Serkkola (2018) where the lack of quality data has an impact on the projections used to plan current and near-future waste and resource management strategies. Indeed, plans for waste infrastructure are often based on inaccurate data that can lead to the misinterpretation of current circumstances and underpin future scenarios with false assumptions (Salemdeeb et al., 2016; Mukhtar et al., 2016). Another ramification of poor data highlighted by the workshop participants was the negative impact to monitoring and managing historical landfills. Specifically highlighting potential future opportunities in urban mining, particularly in relation to CRM's, the workshop participants agreed with the literature (e.g. Bardi et al., 2016; Krook and Baas, 2013; Ongondo et al., 2015) regarding practical feasibility, limitations of poor data availability and the need to maximise such resources in the future.

The continued reliance on traditional system structures was also highlighted as a barrier. In the traditional economic model, the system (and its actors) are focused to sell, and possibly due to resistance by the 'top dogs', producers are hesitant to enact change (such as enabling reuse and repair functions) within their business models in order to protect sales (as highlighted by the lobbying impacts to EPR implementation in the finance section). However, the transition to the circular economy requires radical change, which in turn needs a new way of thinking and doing business across sectors and industries (Bocken et al., 2016). As such, this barrier can be expanded to include all sectors along the value chain, not just the waste and resource management sector. Also linked to these traditional system structures is the continued engagement with low waste hierarchy strategies such as incineration and landfill, where participants highlighted the continued building, and thereby increasing capacity, of such facilities. These limitations mirror those reported in the literature, where too little emphasis is place on strategies that have higher prioritisation on the waste hierarchy (Mazzanti and Zoboli, 2009; Fischer, 2011; Gharfalkar et al., 2015; Van Ewijk and Stegemann, 2014).

To overcome structural barriers caused by the continued use of traditional approaches, the development of tools to promote innovative and creative business models as alternatives was suggested by the workshop participants. One method put forward was a Return on Investment (ROI) analysis. An ROI analysis determines the level of benefit generated from a specified amount of investment and can provide a common platform on which to compare competing interests or strategies (Howard et al., 2016). Ghisellini et al. (2016) argues that for a successful transition to the circular economy, there needs to be an economic ROI that provides a suitable level of motivation for companies and industry to make the changes necessary. A similar motivation could be provided through the adoption of circular business models, where the aim of a business, shifts from generating profits via product sales to generating profits via the flow of materials and services over time. Indeed, circular business models have been identified as a way to support the transition by enabling economically viable ways to reuse products and materials whilst utilising renewable resources (Bocken et al., 2016).

Workshop participants also highlighted the absence of external validation for systems, processes and strategies. This includes the lack, or misalignment, of international standards and definitions as well as limited monitoring and performance testing. The lack of a common language, even within one sector, means that efforts to standardise systems and coordinate strategies across the value chain is limited. Furthermore, workshop participants noted that the absence of standardisation could create further issues regarding traceability and accountability. Indeed, the lack of harmonisation and standardisation has also been shown to restrict and isolate markets and limit planning decisions thereby resulting in inappropriate infrastructure and under-developed markets (Schreck and Wagner, 2017; Delgado et al., 2009; Mukhtar et al., 2016).

To overcome structural barriers to the circular economy, i.e. issues related to the poor collection and management of data, standardisation and consistent use of data collection tools was suggested. While this seems an obvious step to take, and participants argue could overcome issues associated with traceability and accountability, implementation of a standardised global data collection system may be difficult as it conflicts with the basic principles of sovereignty, i.e. complete selfsufficiency in domestic and international policy where a nation will claim supremacy in the former and independence in the latter (Marsonet, 2017). While sovereignty is often distributed between supranational, national, subnational, and sometimes regional and municipal units, the coordination of international policy has so far been limited (Marsonet, 2017).

The operational barriers highlighted by the workshop participants include the practicalities of waste collection and management as well as a lack of knowledge exchange across sectors. In collecting and managing wastes, the primary purpose of waste management has been to reduce harmful impacts to the environment and human health arising from the indiscriminate disposal of untreated waste. In developed countries, this purpose has since evolved to encompass resource recovery (Mukhtar et al., 2016). In the EU, the implementation of the waste hierarchy has led to progressively more sophisticated waste management strategies. While the waste hierarchy can be said to align to circular economy principles when fully implemented, it has been argued that the limited specification of prevention strategies, the absence of quantitative targets for reduction or reuse, and the lack of a distinction between open- and closed- loop recycling could constrain dematerialisation and resource effectiveness (Van Ewijk and Stegemann, 2014; Gharfalkar et al., 2015). Challenges to effective resource management are further created by inconsistent local legislation and misaligned supranational policy. Here, legislation and regulations were noted to be divergent between and within nations, leading to a range of strategies employed internationally, and at a local level, non-uniform schemes across local authorities, e.g. recycling schemes employed by local authorities in the UK (Bees and Williams, 2017; Parfitt et al., 2001). Even historical policy has been identified to have a continued impact on future resource management, whereby urban mining has been limited due to poor waste management and data collection approaches, for example approaches to landfilling waste did not traditionally separate, or note the location, of hazardous materials.

To overcome perceived inconsistencies and divergence in policies, regulations and strategies, standardisation and unification of standards and systems was promoted. While it could be argued that the CEP is attempting to achieve this, its level of success is yet to be seen. Considering EU waste and resource policy pre-CEP was largely successful in its attempts to standardise waste and resource management and strategy (Wysokińska, 2016), disparity between member states is still evident. This has been due to the flexibility in level of transposition that member states are given, i.e. member states can choose to transpose EU policy at the level of 'copy-out', 'gold-plating' and 'no gold plating' (Anker et al., 2015). This highlights a conflicting aspect of supra-national environmental policy, whereby the overarching policy must try to promote certain objectives and targets but allow member states to choose methods of implementation and thereby maintaining national sovereignty.

With respect to schemes implemented at a local level, workshop participants also noted that success can be hampered by the dispersal of low-grade materials across a large area and by existing contractual obligations. Indeed, with capital costs in the hundreds of millions of Euros and operating contracts exceeding multiple decades (Nixon et al., 2013), there is a significant chance that facilities commissioned, and contracts signed, in the present (and near future) will be at risk of technological, and contractual, lock-in. In the case of contractual lock-in, local authorities are committed to supplying contracted quantities of waste over decades, regardless of changes in waste composition, volumes and policy (Schneider and Ragossnig, 2015). To overcome barriers caused by contractual lock-in, the inclusion of flexibility and / or different options that could be enacted when conditions change was suggested. With a similar approach included within CCR policy, the inclusion of flexibility and / or options within waste and resource management policy could be developed. This could include the phasing out of incineration, through the use of incremental limitations or taxes, and the promotion of future urban mining through the collection, storage and dissemination of good quality data during current landfilling activities (i.e. record which exact materials are landfilled where, in addition to current data that records tonnage).

Finally, the workshop participants identified a potential lack of quality knowledge exchange, with poor dissemination of good practice, within and outside the sector (public, private and industrial). As well as poor transparency and accountability of information within the sector. Ineffective infrastructure and poorly connected supply chains, particularly with respect to secondary materials markets and the use of recycled materials, were also highlighted by the workshop participants. A point that is in agreement with Salemdeeb et al. (2016) who argues that the waste and resource management sector plays a vital role across interconnected but often fragmented sectors. They also note that waste generation (and therefore management and utilisation) is difficult to quantify at all stages of the supply chain, and that the availability of insufficient data causes a barrier to progressive waste management and secondary material utilisation.

Technological innovation has not only changed the ways in which waste is collected and treated but also the composition. New materials and products have led to a huge diversification in waste composition. Participants noted this proliferation in materials and products, and in particular participants drew attention to composite materials, biodegradable materials and Nano-materials as examples. Furthermore, they highlighted potential limitations in the consumption of new materials, where they may create complications for future waste management and thereby hinder the transition to the circular economy. Technological innovation, with respect to the collection and treatment of waste, not only has to address materials and products in the current waste stream, but also remain flexible enough to cope with new, and ever more complicated, materials and waste streams. This mirrors the problems faced by the energy sector, whereby infrastructure commissioned now needs to take into account changes to future technology, policy and practice. Major changes to products and systems, at all levels of the value chain (i.e. in production, distribution or during end-of-life management) that have been driven by innovation and advancing technology, have created stakeholder uncertainty regarding costs and level of adoption. Furthermore, concerns have been raised regarding the quality of materials and products that are designed with circularity in mind, i.e. made from recycled / secondary materials (Ritzén and Ölundh Sandström, 2017). This concern was shared by the workshop participants who questioned the quality of products made with significant recycled content and what implications that may have on end of life management options in the future.

While it was acknowledged that process technology would continue to develop in line with new materials, the long lifespan of facilities may lead to technological lock-in, whereby the utilisation of more efficient technologies is limited.

To overcome technological barriers concerning the introduction of novel / new materials that may be difficult to reuse or recycle, the application of eco-design principles in the development stage was suggested. Eco-design and other such approaches (e.g. regenerative-design, design for recycling / design for disassembly) could play a critical role in the transition to the circular economy by designing out resources through dematerialisation, enabling regeneration and recycling and by extending the product lifespan through increased durability, repairability, and the standardisation of components (Lieder and Rashid, 2016; Wysokińska, 2016). However, the success of eco-design, specifically increased recyclability, regeneration and repairability, also depends on the availability of suitable technologies and facilities to manage end-of-life processes (Maris et al., 2014). Thereby, as well as the recyclability of the material / products itself, eco-design should also consider the availability of technology and facilities required to process the material / product. Furthermore, the successful implementation of eco-design is dependent on the social acceptability of recycled materials, where material traceability (and therefore a need for cross-sector information) has been determined to be a prerequisite (Maris et al., 2014).

The workshop participants considered consumer behaviour to be a major barrier to the circular economy. This aligns with current literature that notes the role of the consumers (i.e. those that buy and dispose of products), particularly with respect to material recovery, where participation strongly impacts the success of waste management strategies (Triguero et al., 2016; Babaei et al., 2015; Bulkeley and Gregson, 2009). However, a general lack of public awareness and participation has been found to limit implementation and thereby success (Babaei et al., 2015). The specific consumption behaviours highlighted by the workshop participants were; divergent levels of engagement with, or awareness of, recycling and reuse activities, a lack of understanding regarding the concept of the circular economy, and, behaviours that are dictated through (fast) fashion. Fast fashion is a business model where the life-cycle of a product is shortened, often to a month or less, and consumers are encouraged to purchase low-cost, fashionable products impulsively and in increasing amounts. Consumers of fast fashion have been found to hoard and dispose of unwanted (no longer fashionable) products rather than participate in recycling, even when they had positive attitudes towards the environment (Joung, 2014). Thus, a disconnect is highlighted between consumer attitude and action, particularly where engagement with recycling and reuse activities is concerned. The workshop participants agreed that reuse is only attractive to those who are environmentally aware or those with limited levels of income.

With respect to recycling, contamination and the consumption of products that use low-quality materials was suggested to impact the quality and therefore the use of recyclates within the production chain. Thereby, diminishing any positive impacts.

Participants identified that the waste and resource management sector is placed within a socio-technical system that relies heavily on both political will and public engagement to push forward further progress. In particular, the role of public acceptance / behaviour was highlighted as well as policy and legislation in driving forward the waste and resource management sector in order to contribute to the circular economy. This also agrees with Mukhtar et al. (2016) and Throne-Holst et al. (2007), in that the public have an active role to play in the transition to the circular economy by acknowledging, and acting upon, the connection between consumption and waste generation. However, poor links (and a lack of social inclusion) between research / innovation, education and business was highlighted as a barrier, along with the poor understanding of the circular economy concept and knock on implications for consumers, industry and governments.

To overcome barriers concerning attitudes and consumer behaviour, the need to change attitudes by increasing awareness of consumption and consumerism was suggested. However, attempts to raise awareness have so far fallen short with policies fostering green consumption (consumption of goods based on pro-environmental claims) rather than sustainable consumption (consumption of a good only when it is the most sustainable option). This focus on green consumption is argued to be contradictory, where the consumer is at once responsible for maintaining the traditional function of economic growth as well as driving the system towards the systemic changes that are required for sustainability (Akenji, 2014). The workshop participants note that the effectiveness of awareness campaigns can also be divergent between demographic groups, particularly where age is considered. As such, it was suggested that policy should take a long-term view where engagement starts with the young, who are then continually re-educated throughout school, higher education, further education and work place schemes. To aid this, stronger links between the education sector, main market players and innovation / start up scene were suggested.

Specific behavioural issues could also be addressed individually. For example, with the stimulation of de-hoarding to reduce the level of legacy wastes in the future, and the use of role models (i.e. celebrities / social media influencers) to deprioritise fast fashion. The “Attenborough Effect” is an example of where a role model has influenced behavioural change. During the documentary, Planet Earth II, the narrator (Sir David Attenborough) issued a call to action to combat plastic waste. In a consumer survey, market research group Global Web Index found that over 50% of consumers reduced their use of single use plastics in the twelve months after the programme was aired (Bayindir et al., 2019).

When asked if the concept of ‘readiness’ could be applied to the waste and resource management sector with respect to the circular economy, most participants voted yes (n=12). One participant voted maybe (n=1), adding that it had the potential to be useful but that more thought and planning would be required. None of the participants disregarded the concept outright (n=0).

7.3 Circular economy readiness themes within the waste and resource management sector.

Taking into account the barriers and solutions discussed by the workshop participants, the following five themes for circular economy readiness were developed; enhanced data availability, greater harmonisation, improved consumer behaviour, reduced system fragmentation and application of eco-design principles.

1 Enhanced data availability

Poor quality and availability of data was highlighted as a structural barrier; however, it also has ramifications across the other themes, particularly financial (e.g. informing the viability of urban mining), operational (e.g. informing policy, infrastructure requirements and implementation success) and attitudinal (e.g. for improved understanding and perception of circular economy principles). Here, improvements to data collection, quality, curation and dissemination are required to improve the traceability, accountability and knowledge of the materials and resources currently in circulation. Thus, an immediate recommendation would be to develop an internationally standardised system to collect, curate and access data concerning the collection and management of wastes and recycled materials.

2 Greater harmonisation

The lack of harmonisation with respect to policy, regulation, standards and practice were highlighted as structural and operational barriers. As this also impacted the dissemination of information and good practice, the lack of harmonisation has ramifications for financial and attitudinal barriers. Therefore, greater harmonisation is recommended. This would include the standardisation of legislation, regulations and standards at an international level (an international definition of waste would be a good start) and the supported dissemination of good practice and information to all stakeholders.

3 Improved consumer behaviour

Poor consumer behaviour is acknowledged to limit the awareness, engagement and action of consumers with respect to environmentally aware activities, providing a major barrier to the transition to the circular economy. Here, mechanisms whereby consumer attitudes and behaviours could be addressed, and changed for the better, are promoted. Mechanisms could include; increased consumer awareness and education of consumerism, de-prioritisation of fast fashion in favour for resource efficiency, and to include, and engage with, all stakeholders, not just “the converted” or those who participate out of necessity. Here, engagement with consumers is recommended to start at an early age, starting in pre-school education, then continually revisited throughout the different stages of education (primary, secondary, further and higher education) and on into the workplace.

4 Reduced system fragmentation

Fragmentation of systems, sectors and markets have created financial, structural and operational barriers to the circular economy. To reduce fragmentation, the move from a market (value-based) economy to a service (product-based) economy is suggested. This would require rethinking business models to remove the emphasis on sales / value creation, and to promote the connection and collaboration of multiple sectors (private, public and third party), multi-level organisations (international, local and start-up) and all members of society (public, business leaders and academics). Collaboration of sectors and stakeholders at all stages of the supply chain is also suggested alongside the relinking of secondary material markets with primary production chains (potentially through market instruments and financial incentives).

5 Application of eco-design principles

The development and consumption of new (e.g. composites) and novel materials (e.g. Nano-materials) have been highlighted as both technological and operational barriers whereby the management at end-of-life is unknown and, in some cases, may render existing recycling / recovery processes inefficient. To overcome this, the comprehensive application of eco-design principles by the producers during the development stage is recommended. Here, consideration of end-of-life management for such materials and products should extend beyond its recyclability, to include the technological readiness of recycling / recovery processes as well as suitability of existing infrastructure to enable the collection, transport and management of such products / materials.

7.3.1 Development of the circular economy readiness concept

By completing an initial scoping exercise, key themes that should be included within the concept of circular economy readiness have been identified. To develop the concept further, these key themes should be used to create a framework from which circular economy readiness can be conceptualised, and a range of suitable matrices developed to allow the review and monitoring of sectors.

Within waste and resource management literature, there have been several attempts to develop an index or matrix to encapsulate readiness and specific elements of the circular economy.

Several studies have expanded on the use of TRLs and applied them to waste and resource management, specifically in relation to the management of composite materials at end-of-life (e.g. Rybicka et al., 2016; Sultan et al., 2017). Composite materials are created when traditional materials such as metals, thermoplastics and organic fibres are combined to create new materials that have increased strength, reduced weight and / or enhanced durability (Rybicka et al., 2016; Yang et al., 2012). However, due to the inherent heterogenous nature of composites, recycling is difficult and commercially viable methods to recover the individual components from composites are limited (Yang et al., 2012). Rybicka et al. (2016) combines TRLs with the waste hierarchy to produce a two-dimensional framework, based on an “ease-effect” grid. Using this framework, strategies for recycling composite materials (specifically, carbon fibre and glass fibre) were compared by Rybicka et al. (2016). Strategies that were placed high on the waste hierarchy and use mature (commercially viable) technology were labelled as desirable, whereas strategies that placed low on the waste hierarchy and had immature technologies were not deemed viable. For the strategies that did not fit into either of these categories, Rybicka et al. (2016) labelled strategies that were in earlier stages of technological development (TRL levels 1-6) but aimed high on the waste hierarchy as having innovation potential, and the converse (strategies with mature technologies that placed low on the waste hierarchy) as requiring re-thinking.

While the value of the reclaimed material is acknowledged to have an impact on a waste hierarchy placement, this framework only measures the intent of the end-of-life management strategy selected (i.e. this framework does not take into account the availability of existing infrastructure or availability of an end-market for the resultant material). This narrow focus however, does indicate that a wider systems perspective should be used when selecting waste management strategies.

An index that does attempt to include a measure of material value is the Recycling Desirability Index (RDI), developed by Sultan et al. (2017). Based on three elements, RDI has been introduced to determine whether a product should be prioritised for recycling. The first element employs TRL levels to determine the readiness of technology to recycle the product. The second element uses a complexity index to determine how technically challenging it is to separate the materials within the product and thus recycle them. The Complexity Index quantifies the complexity of separating constituent components or materials from a composite material. It is based on the Dahmus and Gutowski (2007) model, which considers the number of steps required in separating a component or material, the mass of each separated fraction and the total mass of all materials combined. Finally, the RDI includes a measure of material value, where the third element uses a Material Security Index (MSI) to determine the criticality of materials present in the product. The MSI measures the availability and accessibility of individual resources within the composite. It utilises an existing system, developed by Morley and Eatherley (2008) that ranks 60 insecure materials based on material risks (global consumption levels, substitutability, global warming potential and total material requirement) and supply risks (scarcity, monopoly supply, political stability and climate change vulnerability). The MSI for a composite is the sum of all its component materials. These three individual measures are then combined to give a measure of desirability, where a larger number indicates greater desirability. To test this concept, Sultan et al. (2017) applied the RDI model to twelve relevant products (car battery, mobile phone, PET bottle, DVD-R, desktop computer, wind turbine 100 kW, wind turbine blades 20kW, wind turbine blades 5 kW, refrigerator, tyre, coffee maker and an ergo chair). Out of these products, the model suggested that car batteries, mobile phones and PET bottles should be prioritised for recycling. However, when the virgin material value was also accounted for, the wind turbines (particularly the large 100 kW) gained increased prioritisation, whereas PET bottles, being relatively cheap to produce from virgin materials became the least prioritised.

A common limitation across these two indices is the continued focus on end-of-pipe solutions, where interventions higher up the supply chain, and thus higher in terms of waste hierarchy priority, are not considered. For example, both indices have been applied to composite materials, however neither asks the question regarding the appropriateness of using composite materials in the first place, and why products are being produced that cannot be easily recycled. This is also a notable feature of another index, which aims to measure waste management strategies at a national or local level based on circular economy principles.

Introduced by Pires and Martinho (2019), the Waste Hierarchy Index (WHI) attempts to determine waste hierarchy implementation in a quantitative and holistic way. The WHI considers assigning different levels of contribution of the waste hierarchy priorities to the circular economy. For example, activities that align with prepare for reuse and recycling definitions are valued as 1 x tonnage. Activities that align with down-cycling, energy from waste and biological treatment definitions are given values that vary between 0 and 1 x tonnage, and activities that align with incineration (without energy recovery) and landfill definitions are valued as (negative) -1 x tonnage. For systems that employ a variety of activities, these values are then added together and divided by the total tonnage to provide an overall WHI value (Pires and Martinho, 2019). To determine the variable values allocated to down-cycling etc. two scenarios were used. In the first scenario, all activities are equal to 0.5, i.e. half the value of recycling or preparing for reuse, and in the second scenario down-cycling and biological treatment were assigned a value of 0.8 and energy from waste was assigned a value of 0.2. While these scenarios were based on arbitrary values, Pires and Martinho (2019) raises the question of how to evaluate, and thus assign values, for these different activities. A potential solution suggested by Pires and Martinho (2019) could be to base the assigned value on the number of times a material can be recirculated. While this index does attempt to differentiate further between strategies in terms of the value of the reclaimed material and provides an indicator to assess change over time, no attempt is made to include the top priority for the waste hierarchy. By excluding a coefficient for reduce; this index does not consider the system beyond the end-of-pipe solution viewpoint.

Outside waste and resource management, several studies have employed metrics and indices to determine level of implementation of circular economy principles on a broader systems-level approach (e.g. de Wit et al., 2018, Elia et al., 2017 and Parida et al., 2019). The Global Circularity Metric (GCM) was developed by the Circularity Gap report (de Wit et al., 2018) to compare the use of extracted (primary) materials with recycled or recovery (secondary) materials on a global scale. Like the RDI, the GCM can provide a value from which annual improvement can be assessed (Sultan et al., 2017; de Wit et al., 2018). The GCM is based on a simplified material flow analysis, which takes into account global resource extraction, use of cycled resources and resource outputs (municipal waste, emissions and dispersion) (de Wit et al., 2018). By conceptualising these material flows and stocks, de Wit et al. (2018) have identified four fundamental dynamics that underpin the metric: minimisation of resource extraction, minimisation of material loss and dispersion, optimisation of stock utilisation and optimisation of material cycling through reuse. However, it is the latter (cycling of materials) that has been identified as the key dynamic, and thus has been used to measure circularity as the *"share of cycled materials as part of the total material inputs into the global economy every year"*.

A metric that acknowledges the complexity and inter-connectedness of sectors and companies, and how this contributes to the transition to the circular economy, is the Ecosystem Readiness Assessment (ERA) developed by Parida et al. (2019). It is based on three elements. First, the external trend assessment which analyses technological, market and regulatory trends that may directly or indirectly affect the business ecosystem. In the ERA, the ability of the company to use this knowledge to inform business model transformation is also measured. The second element involves taking stock of the company's business model and identifying areas of improvement, and what implication such improvements would have on the ecosystem partners. Finally, the third element focuses on the ecosystem partners, where the roles and responsibilities of existing ecosystem partners, and the need, and potential, for new partners are assessed. When all three elements are taken together, the gap between circular aspirations (i.e. what is defined by external forces) and the capability of the ecosystem to deliver these aspirations is established. This gap reflects what is needed for the transition to succeed, e.g. concerning capabilities, resources, governance structures, etc. As a qualitative tool, the ERA attempts to provide a starting point from which companies can prepare (i.e. coordinate themselves and existing ecosystem partners, identify new ecosystem partners and identify associated opportunities and risks) to undertake transformative processes in the transition to the circular economy. However, it does not create an indicator to measure success or allow comparison between companies and sectors (as ERA is based on the factors influencing the lead company in an ecosystem).

Up to this point, all the metric and indices discussed have employed ad-hoc methodologies. Indeed, in a review of 16 studies that sought to evaluate the circularity of a system, 43% were found to have employed mixed- or ad-hoc methodologies (Elia et al., 2017). In addition to these ad-hoc methodologies, Elia et al. (2017) argues that there are a range of existing environmental assessment methodologies, primarily based on life-cycle thinking, that could be used to evaluate circularity. These existing methodologies differ by type (single indicator vs. multiple indicators) and parameter (materials flow, energy flow, land use and consumption or other) and include water footprint, material flow analysis, Emergy analysis, Ecological footprint and Life Cycle Assessment. However, only 19% of the literature reviewed by Elia et al. (2017) were found to adopt well-known index methods. Furthermore, over half (58%) of the studies assessed, were found to focus on strategies that provided interventions at a macro level, whereas only 25% and 19% focused on strategies that provided interventions at a meso and micro level respectively.

Overall, this review of existing indices and metrics has highlighted the potential complexity, and indeed difficulty, researchers may face when developing appropriate metrics and indices for the concept of circular economy readiness. A starting point may be the development of a definition to encapsulate the concept of circular economy readiness. Here, the identification of key themes has allowed for the development of an initial definition, where the concept of circular economy readiness is suggested to be:

The future-proofing of current sectors and/or systems to ensure barriers to the circular economy are eliminated, reduced or can be overcome, such to allow the successful transition to the circular economy in the future.

In developing the concept further, it is important to consult with stakeholders across a range of sectors and industries, to ensure the final definition for circular economy readiness encapsulates all important aspects.

While this study has focused on one sector, the waste and resource management sector, a concept such as circular economy readiness should be applied across multiple sectors and systems (e.g. throughout design and production) (Su et al., 2013; Kirchherr et al., 2017). By acknowledging the system as a whole, this would mirror the circular economy concept itself, where sectors and industries should avoid individual silos and encourage stakeholder engagement. This is of particular importance where a system has a social aspect, i.e. socio-technical systems such as waste and energy sectors (Mukhtar et al., 2016; Throne-Holst et al., 2007).

While the energy sector, and the use of CCR was used as a basis for this chapter due to similar characteristics (e.g. both sectors having conflicting priorities), differences are present that should be reflected in the development of circular economy readiness. For example, unlike the energy sector, future proofing the waste and resource management sector requires a broader focus than just "technological readiness", which is present in CCR. Indeed, changes to societal and institutional behaviours and attitudes are also required. Therefore, the development of "societal readiness" along with technological readiness should also be encapsulated within the circular economy readiness concept.

Socio-technical systems have been shown to generally develop incrementally along established developmental pathways (Jedelhauser and Binder, 2018; Geels., 2010). The concept of circular economy readiness could help break this status-quo, by identifying not only how the system contributes to the implementation the circular economy but also how it will help the transition. Here, a fundamental shift towards more sustainable models of living is required, which takes into account alternative socio-technical innovations that are often developed in niches (Jedelhauser and Binder, 2018). Similar to the first stage of an ERA (Parida et al., 2019), the circular economy readiness concept should identify potential factors within existing systems that may create a barrier to the future transition and seek solutions to eradicate or overcome them.

As changes to one part of a socio-technical system will cause subsequent changes to other parts, in the transition to the circular economy, strategies must also consider the system holistically (Challenger and Clegg, 2011). The concept of circular economy readiness considers enhanced data availability, greater harmonisation, improved consumer behaviour, reduced system fragmentation and application of eco-design principles as key solutions. To enable these solutions, all aspects of a socio-technical system, i.e. people, processes and procedures, goals, culture, technology, and buildings and infrastructure, should be included and given joint consideration (Challenger and Clegg, 2011).

7.4 Chapter summary

This chapter has shown that the concept of readiness could be applied to the waste and resource management sector in preparation for the transition to the circular economy. The use of a workshop allowed participants with different experiences, viewpoints and priorities to discuss how the waste and resource management sector can contribute to the transition to the circular economy, what barriers are present that may limit the transition and what solutions can be implemented in readiness for the circular economy.

Feedback from the workshop highlighted the role of the waste and resource management sector, namely the provision and preservation of resources, in the transition to the circular economy. This corroborates the argument made by Salemdeeb et al. (2016) that the waste and resource management sector has a vital role to play in the transition to the circular economy by maintaining and recirculating resources and materials within supply chains. Furthermore, participants identified that the waste and resource management sector is placed within a socio-technical system, which relies heavily on both political will and public engagement to push forward further progress. In particular, the role of public acceptance and behaviour was highlighted, as well as policy and legislation, in driving forward the waste and resource management sector to fulfil its potential contribution to the circular economy. This agrees with Jedelhauser and Binder (2018) and der Merwe et al. (2018) who advocate the use of soft infrastructure tools such as social mechanisms and institutional regulations alongside hard infrastructure (i.e. technological innovation) in the transition to the circular economy. It also supports the conclusions of Mukhtar et al. (2016) and Throne-Holst et al. (2007), in that the public have an active role to play in the transition to the circular economy by acknowledging, and acting upon, the connection between consumption and waste generation.

Using the generic barriers suggested by Ritzén and Ölundh Sandström (2017), participants identified a range of sector-specific barriers. Financial barriers included who is responsible for paying for waste management, shrinking waste management budgets and a pressure on operators to show satisfactory value for money. Another financial barrier highlighted was the level of capital expenditure required for the installation and operation of new waste treatment facilities. Here, long financial payback periods can lead to lock-in scenarios, as seen within the energy sector and highlighted by Corvellec et al. (2013) as well as Markusson and Haszeldine (2010; 2009).

The poor quality (and sometimes total lack) of data regarding waste generation, treatment and composition was highlighted by the participants as a barrier to progressive waste management and for the future mining of CRM's. This agrees with Mukhtar et al. (2016), who argued that insufficient information can cause a barrier to effective planning with regards to waste management strategies and infrastructure, and with Ongondo et al. (2015) and Krook and Baas (2013), who both highlighted the role of poor data availability in limiting urban mining.

Ineffective infrastructure and poorly connected supply chains, particularly with respect to secondary material markets and the use of recycled materials, were also highlighted by participants and align with the operational barriers described by Ritzén and Ölundh Sandström (2017). This agrees with Salemdeeb et al. (2016) who argues that the waste and resource management sector plays a part across interconnected but often fragmented sectors, and that waste generation, and therefore management and utilisation, is difficult to quantify at all stages of the supply chain. Here, the lack of sufficient data and information again causes a barrier to the progressive management and utilisation of wastes and resources.

Perhaps the greatest limitation to the waste and resource management sector in the transition to the circular economy are attitudinal factors such as consumer behaviour. Consumer behaviour influences what products are purchased, degree of product utility, when products and materials are disposed, and how they are disposed of. Furthermore, consumer behaviour and attitudes can affect waste management infrastructure, as certain strategies are favoured, and others are vilified, and authorities must prove value for money when taxpayers' money is used to finance local waste management systems. This agrees with Mukhtar et al.

(2016) and Throne-Holst et al. (2007) who highlight the role of the consumer as key stakeholders in the generation, collection and treatment of waste.

Technological innovation has not only changed the ways in which waste is collected and treated, but also the composition of waste streams. Workshop participants noted this proliferation in materials and products, drawing attention to composite materials and Nano-materials as examples. Participants also highlighted the increased risk that the increased availability and consumption of such materials would complicate future waste management, and thereby hinder the transition to the circular economy. Thus, technological innovation with respect to the collection and treatment of waste has to consider not only materials and products in the current waste stream, but also remain flexible enough to cope with new, and ever more complex, materials and waste streams in the future.

Participants suggested a wide range of solutions that could address the barriers discussed in readiness for the circular economy. These solutions can be categorised into five main themes; enhanced data availability, greater harmonisation, improved consumer behaviour, reduced system fragmentation and application of eco-design principles. In readiness for the transition to the circular economy, it is recommended that these five themes are incorporated into any framework or matrix developed. Here, the concept of circular economy readiness is advocated as an approach to frame the five key themes, as well as to address the need, both within the waste and resource management sector and more broadly within product development and supply chain management, for future proofing.

CHAPTER 8: Conclusions and Recommendations

8.1 Chapter introduction and outline

This chapter provides a synthesis of Chapters 4 – 7 and presents the primary conclusions and recommendations of this research. Also discussed within this chapter is the contribution to knowledge, implications to theory, policy and practice, as well as limitations and further lines of enquiry.

8.2 Defining the grand societal challenge.

To address the issues of unsustainable consumption, the transition to the circular economy has been recommended as an alternative approach to the dominant (linear) economic paradigm (Section 2.2.1). While there is widespread acknowledgement for the need to transition to the circular economy, a standardised definition or understanding of what this transition entails has been lacking. This lack of definition and understanding has been attributed to both the evolving nature of the concept and the use of the concept by stakeholders from different disciplinary or industrial backgrounds. To overcome the lack of a standardised definition, this study has unpicked the circular economy to describe the concept in terms of aims, core concepts and principles, and enablers of the circular economy (Section 2.3.2).

The aims of the circular economy are to encourage economic prosperity, ensure environmental protection and promote social equity, both for current and future generations. To achieve these aims, several inter-linked core concepts and principles are promoted. These include resource efficiency, life-cycle thinking and sustainable consumption and production, as well as transformational change that avoids lock-in and decouples resource use from economic growth. This will require the promotion of enablers that introduce measures and instruments that encourage alternative business models, develop secondary markets for materials in the waste stream, recognise consumers as key actors and encourage technological innovation and investment. These enablers require the acknowledgement and engagement of stakeholders at multiple levels.

While there is international recognition for the need to transition to the circular economy, several barriers to widespread adoption have been identified (Section 2.3.4). Barriers can be financial (initial investments and ongoing viability), structural (lack of standardised systems, information availability and sector isolation), operational (poor infrastructure, restricted markets and complicated policy and regulation), attitudinal (tendencies towards risk aversion, poor consumer behaviour and entrenched institutional conventions) and / or technological (poor design, limited integration and untested materials).

These barriers are comparable with those identified within waste and resource management policy, which can be limited by poor levels of stakeholder engagement, un-coordinated use of measures and instruments, technological lock-in and a continued focus on end-of-pipe solutions. These limitations are further exacerbated by the disparity in waste management systems across different nations, where the need for sanitary waste management remains the top priority for some nations, particularly in less developed economies.

The role of waste and resource management policy in supporting, (or conversely frustrating) the transition to, and implementation of the circular economy has been highlighted by similarities with the zero-waste concept, adoption of the CEP and the effective use of the waste hierarchy to improve resource efficiency (Section 2.5.2). However, for waste management policy to be effective in supporting the transition to the circular economy, action is required to identify existing limitations and barriers as a first step towards addressing these shortcomings.

8.3 EU waste policy - Probably the best waste policy in the world…or is it?

With one of the most advanced policy frameworks in the world, the EU has been described as a leader in environmental policy. However, limitations have also been acknowledged. This research has identified three key barriers within current EU waste policy that may limit the transition to the circular economy in the future. These are (i) a focus on near-term targets, (ii) poor harmonisation (even within a single country) and (iii) lack of engagement with stakeholders across the full value chain.

8.3.1 Focus on the near-term

Over the past two decades, EU waste policy has driven a massive change in the waste strategies employed by its member states. The continued promotion of the waste hierarchy, in combination with stringent landfill diversion targets, have promoted the use of material recycling and recovery options that have significantly reduced the amount of waste sent to landfill. While these approaches have delivered a marked improvement in waste handling, this research concludes that they are at risk of becoming entrenched, and thus have the potential to become restrictive in the transition to the circular economy.

Current EU waste policy, by prioritising landfill diversion, has placed an unbalanced emphasis on mechanisms that address issues at the bottom (low priority) of the waste hierarchy, after wastes have been generated. This was highlighted in the waste strategy documents of the home nations of the UK (Section 4.3.3), where a lack of equivalent emphasis on waste prevention mechanisms (i.e. top priority on the waste hierarchy) was shown. This reflects the lack of waste prevention initiatives / targets within EU policy and is significant due to the requirement of member-states to transpose EU policy, where any limitations within the EU policy approach are also included in national strategies and objectives.

Furthermore, the continued focus on achieving improvements at the bottom end of the waste hierarchy has restricted the ability of waste management systems to address management options at the top. This is illustrated by the increasing prominence of incineration in EU member states (Section 5.2.1). Here, several progressive (wealthy northern) member-states have employed incineration as a means to achieve landfill diversion targets. Driven by near-term targets and long-term contractual / operational obligations, the use of incineration risks technological lock-in (especially due to the significant costs of waste-to-energy infrastructure and the subsequent reliance of states upon this source of energy generation) with the legacy of diverting recyclable wastes away from material recovery.

In addition to incineration, some member-states such as the UK, have utilised MRF and MBT to process waste materials in order to meet EU landfill diversion targets. However, a consequence of this is the production of a residual waste, known as “Fines”, that is hard to treat and for which classification has not been clear. As such, Fines tend to be landfilled. While attempts have been made to clarify the classification of Fines and thus promote further material recovery, this research has identified limitations, for example, the use of inappropriate policy instruments which results in unintended consequences by creating a disincentive to current and future material recovery (Section 6.3). Again, this is evidence that near-term targets can create a barrier to the transition to the circular economy.

While the limitations of near-term targets have become evident in the waste management strategies of the wealthy Northern nations, consideration must also be given to less developed nations that are emulating the development pathways of the former. Within the EU, this has been exacerbated by waste policy that does not differentiate between development statuses. Here, targets are possibly not challenging enough for the wealthy Northern states, but also do not take into account the position, or priorities, of less developed nations.

Thus, balance is needed, where there are sufficient disincentives for activities that impede the transition to the circular economy and / or incentives for best practice. Furthermore, alternative development pathways need to be promoted where the poor strategic decisions made by the wealthy northern nations, driven by the prominence of landfill diversion targets, are disincentivised.

8.3.2 Poor harmonisation

For a balanced policy approach to be successful, harmonisation is required across strategic and operational systems. However, this research has identified that current levels of harmonisation within waste and resource management policy are poor, and thus could create an additional barrier in the transition to the circular economy. Harmonisation was found to be particularly poor with respect to definitions / terminology, classification mechanisms and operational strategies. Often poor harmonisation is exacerbated by the poor quality and limited availability of data and information (Section 7.2.2).

Poor harmonisation of definitions / terminology is illustrated by the imperfect alignment of the four priorities listed under the waste hierarchy and the ten listed by the R-hierarchy. When compared side by side, the waste hierarchy priority of ‘Preparing for re-use’ encapsulates three different R-imperatives, Repair (R4), Refurbish (R5), and Remanufacture (R6), while ‘Recycling’ incorporates two R-imperatives; Repurpose (R7) and Recycle (R8). By providing a less nuanced approach, the waste hierarchy allows for interpretation, where for example in ‘Preparing for Re-use’, activities aligning with R6 are theoretically at the same level of priority as those aligning with R4.

This also has an impact on classification mechanisms and operational strategies, where this research has identified poor harmonisation. Currently, “Material Recovery” targets include materials managed by activities classified as ‘Preparing for re-use’ and ‘Recycling’, which in turn aligns with a full range of R-imperatives

(R4 – R8). While the R-hierarchy acknowledges differences between closed-loop recycling (where materials are processed to achieve the same quality secondary materials) and open loop recycling (where materials are processed, but achieve a lower quality secondary material), such distinction is absent from the waste hierarchy. Implications of a less nuanced approach could be the creation of perverse incentives that fail for example, to incentivise closed-loop recycling over open loop recycling.

This was illustrated in Chapter 5, where energy recovery (incineration) along with the utilisation of the residual waste; Incinerator Bottom Ash (MSW-IBA), has gained prominence within the EU (where members-states achieving the landfill diversion targets, incinerate on average 47%MSW). Here, issues were highlighted concerning the ongoing contractual obligations and long-life span of the technology, which means that recyclates would have to be diverted from closed-loop recycling routes to ensure that the input materials for incineration have a consistent calorific value for efficient energy production. The implications of this are two-fold, the first concerns success in achieving near-term and future targets, and the second concerns the appropriateness of classification.

As Figure 23 highlights, for energy recovery to contribute to current landfill diversion targets (10%MSW by 2035) recovery of all the residual waste produced (either through recycling activities, e.g. metals, or utilised through other recovery, e.g. backfilling) would be required, as generation would be equal to 6-10%MSW. However, this would not meet Material Recovery targets, where only metal recovery is accounted for under current circumstances and would only contribute an extra 0.6-1% in addition to the MSW initially sent for recycling. Thus, the need to include the utilisation of the remaining residual materials (i.e. MSW-IBA) is apparent, where it was concluded that the application of EoW would be required. Here, inclusion of all MSW-IBA utilised after EoW would allow the Material Recovery targets for 2025 (55%) and 2030 (60%) to be met. However, for the most distant target (65% by 2035), and any introduced hence, this route would fall short.

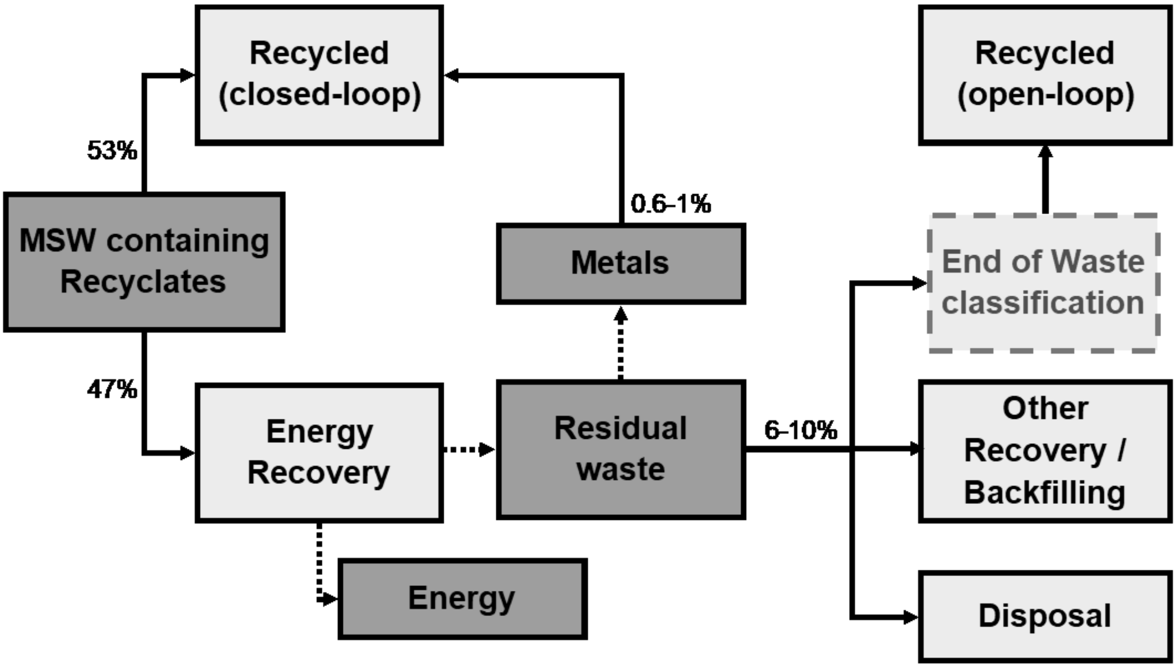


Figure 23: Waste management options for recyclates and residual materials, percentage of total MSW given for each management option, based on average incineration rate of EU member states achieving current landfill diversion target.

The second implication regards the appropriateness of using EoW, and the classification of ‘Recycling’, where residual wastes are concerned. As shown in Figure 23, the utilisation of residual wastes (such as MSW-IBA) with EoW classification has equal weighting as closed-loop recycling with respect to Material Recovery targets. However, in accordance with R-imperative terminology, the utilisation of MSW-IBA would be classed as open-loop recycling, whereby the material is ‘down-cycled’ into a secondary material of poorer value. In addition to being of poorer quality, and thus only achieving one additional life-cycle, concerns specific to the utilisation of MSW-IBA have been raised regarding the loss of appropriate tracking and the potential for environmental harm (e.g. leaching). While it is preferable within the waste hierarchy for residual wastes to be down-cycled and utilised, compared with them being subject to further (other) recovery or disposed of to landfill, more emphasis should be placed on maintaining closed-loop recycling routes, which in the current situation it is not.

These issues are exacerbated by the poor availability and quality of data. For example, the indiscriminate and undocumented disposal of wastes prior to the landfill directive may limit the ability of nations to urban mine in the future (Section 7.2.2). This again, is a pattern being repeated in the development pathway of emerging countries. In more progressive waste management systems, the limited availability of data and information has restricted the development of secondary resource markets, created confusion within waste processing and emphasised the silo-ed nature of waste management. While efforts are being made to collect and utilise data on waste management practices, often this is restricted to use by national governments to inform ongoing waste management strategy and to measure compliance.

8.3.3 Lack of engagement with full value chain

It is acknowledged that the collection and use of good quality (and complete) data and information, not just within waste management but across the full value chain, is required to facilitate the transition to the circular economy. Thus, engagement with the full range of stakeholders (producers / consumers / end-of-life management) is needed. This research has found disparate levels of stakeholder engagement at both strategic and operational levels, and in implementation.

When the level of stakeholder engagement was compared across the waste management strategies of the four home nations of the UK, high levels of disparity was found. All four acknowledged the need to engage with all stakeholders within the full value chain; however, the level of recognition differed between the devolved administrations. For example, while Scotland and Wales recognised the role of consumers as enablers of the circular economy, recognition within England and NI was limited to that of the disposer, to which the service of waste collection is provided. This disparity was also shown with regard to the range of mechanisms employed by the four home nations to engage with stakeholders, where each placed different emphasis on fiscal incentives / disincentives, control and command measures, voluntary initiatives and feedback mechanisms (data collection, consultations, etc.).

Concerning poor levels of stakeholder engagement in implementation, Chapter 6 highlighted an example where stakeholder opinions were consulted during the development of the Landfill Tax (Qualifying Fines) Order 2015 (QFO), but the resultant outcomes where not fully considered. During the consultation phase, stakeholders raised a number of potential limitations including operational aspects and the single-threshold of the 10% LOI limit. While a number of revisions were made, and published in the final version, stakeholders have reported limitations in the implementation of the QFO that mirror those made during consultation. Thus, highlighting a further issue regarding the meaningful engagement with stakeholders to successfully develop and implement policy measures and instruments.

8.4 Recommendations

To overcome the barriers identified by this research, and thereby contribute to the transition to the circular economy, the following recommendations are made. It is recommended that (i) waste and resource management is based on future thinking (and long-term objectives) rather than near-term prioritisation, (ii) harmonisation of strategic and operational objectives is achieved, and (iii) cooperation / collaboration is encouraged between nations at different developmental stages and amongst stakeholders throughout the full value chain.

8.4.1 Future thinking

To overcome barriers related to the continued focus on near-term targets and the associated risk of technological (and contractual) lock-in, more forecasting and future thinking is recommended. This would start with a clear statement of future ambition alongside the ultimate objective / targets. Such future thinking is commonplace in other areas of environmental policy, such as Climate Change. For example, the Paris Agreement provides a clear statement of ambition, with governments agreeing the long-term goal of keeping increases to average global temperatures below 2°C (above pre-industrial levels), with a further ambition to pursue efforts to limit this to 1.5°C. While current national action plans are unlikely to achieve the most conservative target, governments are encouraged to come together every five years to set more ambitious targets and re-evaluate national action plans (EC, 2019).

The development of a concept like Circular Economy Readiness could provide the overarching objectives for international collaboration. However, to overcome the issues of current waste and resource management policy, objectives and targets should consider the costs and benefits experienced by the environment and to society. An example of which, would be to move away from the weight-based targets that characterise current waste and resource management policy, and to utilise alternative methods such as the Waste Metric introduced by the Scottish government. Here, (local authority) targets are based on the carbon footprint of waste streams, and thus prioritises the management of waste streams identified to be the most environmentally and/or socially damaging.

As noted in Chapter 6, for waste policy to best support the transition to a circular economy it should provide the correct amount of sanction and incentive to enhance resource recovery, while ensuring innovation and investment in progressive waste management strategies is not stifled. This implies that enablers are required which allow for the phasing in / out specific strategies and the use of appropriate policy instruments.

To address issues relating to technological (contractual) lock-in, created by certain strategies and technologies, mechanisms should be put in place to enable the phasing out of technologies and/or strategies when appropriate, acknowledging that in the near-term, the use of such strategies and/or technologies will contribute to existing objectives and targets. Again, mechanisms to promote top priorities in the future, while recognising the current need to utilise less-prioritised options, have been introduced in other areas of environmental policy, namely in the renewable energy sector. Under the EU Renewable Energy Directive (RED II), the use of crop-based biofuels, initially promoted to achieve renewable energy targets, are gradually being phased out from a maximum contribution of 7% in 2020 to 0% in 2030 (EC, 2018e).

The impact of employing inappropriate policy instruments was illustrated in Chapter 6, where the use of a sharp threshold in the classification of Fines created a disincentive to further material recovery. Here, it was argued that the use of banding or a sliding scale would be more appropriate and would also provide the correct incentive to promote continued improvement. Furthermore, it highlighted the importance of harmonisation, where the environment-technology-stakeholder interaction is considered both during policy design and implementation.

8.4.2 Harmonisation

The second recommendation of this research is to enable greater harmonisation of terminology, objectives and operational measures. First, this could be applied in a broad context, where the collection of recyclates is termed resource collection, and the term waste collection is applied to ‘black bin’ waste only. By creating a universal language and moving the public consciousness away from thinking that products and materials at the end-of-life are wastes, awareness of the inherent value is created. Thus, a monetary value is placed on the product and/or material.

At an operational level, better alignment of the waste hierarchy with R-imperatives would create a more nuanced approach and thereby promote higher priority management options. For example, the inclusion of closed- and open-loop recycling within the term ‘material recovery’ at the moment places equal priority on both routes. Instead, ‘material recovery’ should be split into two distinct management options where greater importance, and thus incentives are placed on closed-loop recycling. However, it is acknowledged that some energy recovery will take place, particularly in the near-term, therefore incentives should also be put in place that enable material recovery (i.e. open loop recycling) of residual wastes, and thus diverting this residual waste away from landfill. Nevertheless, to ensure that closed-loop recycling is the preferential management option in comparison to open loop recycling, either separate targets / limits should be introduced. Another option could be the introduction of a weighting system where for example, materials processed through open loop recycling are worth half the value of materials processed through closed-loop recycling.

To enable greater harmonisation, improved collection, quality, curation and dissemination of data are required. In turn, this would improve traceability, accountability and knowledge of the materials and resources currently in circulation. To enhance data availability, an immediate recommendation would be to develop an internationally standardised system to collect, curate and access data concerning the collection and management of wastes and recycled materials.

8.4.3 Collaboration and co-operation

Of course, these recommendations to improve future planning and harmonisation requires collaboration and cooperation on two levels. The first being at an international level, where the experiences, priorities and objectives of developed and developing nations are taken into account. Evidence from this research has highlighted that a number of different waste management strategies have been employed by EU member-states to address the same overarching EU objectives. From this, it is important to learn from the development pathways employed by those achieving near-term targets, where future targets and objectives may be difficult to address due to entrenched principles and technological lock-in. To avoid making the same mistakes, new development pathways should be highlighted for emerging economies, where development stages / local priorities are incorporated within policy structures. This could ensure the correct (and potentially different) level of incentive is applied at every development stage to promote continual improvement.

The second level requires collaboration and cooperation from all stakeholders within the value chain. Within the concept of Circular Economy Readiness, this would need an element of social readiness to work alongside the measures that enable technological readiness. A key recommendation is to improve the actions / behaviour of consumers as active participants within the circular economy. Here, it is recommended that engagement with consumers start at an early age, where a circular economy curriculum (aligned with national policy and priorities) is developed to provide education from pre-school and is revisited throughout the different stages of education and within the workplace.

Furthermore, to reduce system fragmentation, collaboration of sectors and stakeholders at all stages of the supply chain should be encouraged. Here, the links between secondary materials markets with primary production chains should be highlighted and could include market instruments such as tax breaks to stimulate, and incentivise the use of, secondary materials. In addition, the application of eco-design principles, already applied to energy-related products (EU, 2019), should be extended to consider end-of-life management for all product types. In turn, this should be ingrained as standard into design and manufacture processes. Here, efforts could be made to extend the use of products beyond their traditional lifespan by increasing recyclability, changing business models from ownership to leasing / service models, improving the technological readiness of recycling / recovery processes and assessing the suitability of existing infrastructure to enable the collection, transport and management of products / materials.

8.5 Contribution to knowledge

This research has collected data and explored systems to assess waste and resource management policy and its potential contribution to the circular economy. It has highlighted issues with clarity of intent, i.e. what the policy is intended to do, and in implementation, i.e. what actions the policy actually leads to. Where, for example, mixed messages, conflicting priorities and uncertainty has inhibited substantive action and long-term thinking. Thus, this research presents a call for clarity and long-term thinking, where not only is a statement of ambition needed but also defined recognition of what that ambition means for all stakeholders across the value chain. Of course, this is easier to determine if stakeholders are engaged in meaningful discussions. Specifically, this research has addressed three gaps in the existing knowledge concerning the contribution of waste and resource management policy to the circular economy.

(Gap 1) Current level of alignment of national waste and resource management policy to circular economy principles.

It is widely acknowledged that EU directives have largely shaped UK environmental legislation over the past two decades, where transposed EU waste and resource management policy has seen the UK reduce its dependency on landfill and introduce advanced processing methods, such as MBT and MRF. As such, it is likely that the introduction of the CEP will have an impact on UK waste policy in years to come. Several studies over the past ten years have assessed UK waste policy (either overarching UK policy or policy implemented by the devolved administrations) in light of general environmental issue and pre-CEP policy (e.g. Scotford and Robinson, 2013; Falmer et al., 2015; Bee and Williams, 2017; Parfitt et al., 2001, etc.). With growing international attention concerning the transition to the circular economy (e.g. with the introduction of the CEP by the EU) this study sought to consider the inclusion of circular economy principles within the current waste management strategies of the four home nations of the UK.

To do this, this study developed a circular economy framework based on circular economy aims, core concepts and principles, and enablers of the circular economy. When applied to the waste strategy documents of the four devolved administrations, this study found disparity among the four home nations, with Scotland and Wales showing greater alignment with circular economy principles than England (and thus overall UK) and NI. This result agrees with previous studies such as Scotford and Robinson (2013), Falmer et al. (2015) and Bees and Williams (2017).

(Gap 2) Management of residual wastes in light of circular economy principles and circular economy-orientated policy.

Waste and resource management policy in the EU has significantly improved waste management, particular that of MSW, over the last two decades. By achieving the ‘easy gains’ through the implementation of MBT and Incineration, member states have significantly reduced the amount of MSW sent to landfill.

However, a consequence of these trends is the generation, and thus required management, of residual wastes such as Fines and MSW-IBA. While the presence, and characteristics of these residual wastes, is often acknowledged within the literature, there is a gap in the knowledge regarding the management of the residual wastes in light of evolving EU and national policy, and how the management of such residual wastes contribute in the transition to the circular economy.

This study has explored the generation and management of two residual wastes in light of national and EU policy. The characterisation and practical (novel) applications of MSW-IBA have been well documented within the literature (e.g. Dou et al., 2017; Margallo et al., 2015; Cheeseman et al., 2005; Allegrini et al., 2015, 2016; Biganzoli et al., 2013; Grosso et al., 2011; Chimenos et al., 2000, etc.). This study contributes to the knowledge by considering the management of MSW-IBA in light of evolving EU policy, specifically with respect to the CEP and circular economy principles.

This study found that the utilisation of incineration, and thus the generation of MSW-IBA, is likely to increase in the future. This is due to EU member states continuing to divert waste away from landfill in light of stringent landfill diversion targets set by the CEP. However, for member states to also achieve current recycling targets, MSW-IBA must be utilised in a way that adheres to the material recovery definition (i.e. not in a backfilling activity). To do that, this study suggests the use of EoW criteria, to classify MSW-IBA as a non-waste, and thus counting towards material recovery targets when used. This approach however, will only work under current waste-related targets.

For future targets, such as the most distant CEP target (65% by 2035), the use of incineration alongside the utilisation of non-waste MSW-IBA would not be enough. This also raises questions regarding the appropriateness of incineration with respect to circular economy principles, where the principles aim to maintain the value of materials / resources while incineration effectively destroys them.

The second residual waste that this study has explored is the management of Fines, generated through the increased utilisation of MBT. Here, a national perspective was taken; where the introduction of specific secondary legislation to classify the nature of fines was found to have ramifications on the objectives of the primary legislation, i.e. landfill diversion. First, this case study reviewed in detail the development and introduction of the Landfill Tax (Qualifying Fines) Order 2015. To date, the author is unaware of any other study that has studied this piece of legislation. Second, based on concerns highlighted within grey literature sources (e.g. Balch, 2014; Coll, 2015; Goulding, 2015a, b, 2016) and at a stakeholder event (CIWM open meeting), this study undertook an opinion survey to understand how well the QFO had been received by stakeholders and its impact on material recovery and landfill diversion.

This study has illustrated an example of unbalanced policy, which has led to unintended consequences for overarching policy objectives. Specifically, the QFO was found to create a perverse incentive, leading to a decrease in landfill diversion by limiting the recovery of secondary materials (an underpinning principle of the circular economy) and discouraging investment in technology (required for the transition to the circular economy). Furthermore, this study has highlighted the key role of stakeholder engagement when developing and introducing new policy instruments. Where it is important to engage stakeholders in meaningful discussions rather than closed consultations.

(Gap 3) Future proofing waste and resource management policy to transition towards, and contribute to, the circular economy.

In a broader context, this study also acknowledges barriers and limitations to the transition to the circular economy discussed within the literature (e.g. Manninen et al., 2018; Moreau et al., 2017; Ritzén and Ölundh Sandström, 2017; Salemdeeb et al., 2016, etc.). Using these barriers as a basis, and focusing on the waste and resource management sector, this study explored ways to future-proof the sector to overcome the barriers and therefore contribute to the transition to, and implementation of the circular economy.

To do this, the concept of readiness has been explored in terms of the circular economy. Completing a scoping exercise, this study has identified five key elements that should be included to ensure circular economy readiness. As an initial exploration of the concept, this study has identified what the concept of circular economy readiness would mean within the waste and resource management sector and started to pontificate on the practical development and implementation of the concept.

8.6 Implications to Theory, Policy and Practice

In conceptualising the circular economy within a framework, this research reflects on the value of employing the circular economy as an alternative to the linear economy. While attempts have been made to provide an all-encompassing definition for the circular economy, due to the breadth and complexity of the concept, often definitions are aligned to one perspective. Thus, rather than condensing the concept into a definition, this study has conceptualised the circular economy by unpicking the following key elements; aim, core concepts and principles, and enablers. From which a research framework was created. By encapsulating these key elements, rather than providing a definition, the circular economy framework allows researchers to achieve an overview of how well circular economy principles are included within a document. Indeed, this framework could be applied to other areas of research, e.g. different sectors, strategies or initiatives, where an overview of circular economy inclusion is required.

In addition, this conceptualisation of the circular economy has been applied to waste and resource management, a sector that has a key role to play in the transition to, and implementation of the circular economy. By focusing on this sector, this study has identified examples of barriers and limitations within current policy that may hamper the circular economy in the future.

This research has also explored the concept of readiness and has attempted to apply existing readiness models to waste and resource management policy in the transition to the circular economy. Whilst initially promoted as a means to assess the integration of new technologies / process, in this version of readiness, the concept of social readiness that encapsulates behaviours, cultures and priorities is also applied.

Of course, while these implications have concerned the waste and resource management sector, implications to other socio-technical systems, and socio-technical systems as a whole, can also be inferred.

The comparison between two socio-technical systems, waste and resource management and energy, has highlighted key similarities and differences. Both systems must adapt and progress in light of grand societal challenges (such as climate change, resource availability and human development), and are often conflicted between providing an adequate service now and provisioning for future changes. The main difference when applying the concept of readiness to these two socio-technical systems is the degree of importance given to technical and social solutions. Whereby the readiness in the energy sector is primarily technical, and, due to consumers having an integral part to play, social readiness has an equally important role as technical readiness in the waste and resource management sector. Thus, when applying the concept to readiness, in the context of the circular economy or other grand societal challenges, to other socio-technical systems it is important to recognise the prominence of societal and technical aspects within the system. By recognising which, if either aspect is dominant, appropriate societal and technical solutions can be developed and implemented.

Furthermore, interaction between different socio-technical systems should be addressed. Where it is important to ensure changes to one system does not have unintended consequences to another. Indeed, this is of particular relevance for the social aspect of the system, where stakeholders for the different socio-technical systems are often from the same population.

This research also has practical and policy implications at national and supra-national levels. Addressing the contribution of waste and resource management policy in the transition to, and implementation of the circular economy, this study has reviewed potential limitations of current policy. From this, a gap between theory and practice has been identified, where the intended outcome of waste policy is often different to that implemented.

To address the limitations concerning existing policy, and thus to provide effective environmental policy to aid the transition to the circular economy, the following features should be present. Policies need to be accessible to all relevant stakeholders, for example, all definitions and means of implementation need to be pitched at a level accessible to the relevant stakeholder. Engagement with stakeholders should be present when both developing and enacting new policy instrument. Here, engagement should go beyond traditional consultation and instead implement meaningful discussions with the stakeholders. The implementation of new policies, instruments and measures should be considered against the existing policy regime, where efforts are made to identify areas where the new policy has impact (positively or negatively) with existing legislature, thus reduce the occurrences of unintended consequences.

With respect to national policy, this study has identified several implications for UK waste and resource management policy. Addressing the elephant in the room, Brexit is a key concern for ongoing UK waste and resource management policy. While the UK will adopt the CEP, the UK is not obligated to adopt any subsequent EU policies. Thus, an overarching UK waste and resource management policy needs to be developed. Historically, overarching UK strategy has been provided by England. As England was found to be the least progressive regarding alignment to the circular economy, it is important that both English and overall UK strategy be improved to align better with circular economy principles. Here, England (and overall UK strategy) can learn from the strategies developed by Wales and Scotland.

Taking a broader perspective, this study has also identified implications for supranational policy, particularly that introduced at the EU level. While current policies have allowed near-term landfill diversion and material recovery targets to be achieved, challenges will become visible for post-2035 targets. Here, EU policy will be required to promote a complete overhaul of existing systems and infrastructure. A message in-line with the transformative aspect of the circular economy. However, this may be limited by current policy regimes that have long-term practice implications. For example, the long lifespan of waste management technology, facilities and contracts have long-term implications, where nations reacting to current policy could, within one investment cycle, be locked-in to processes and management options that do not align with long-term targets and goals. Thus, there is imperative to identify and implement strategies and options now (such as limits to incineration introduced by Scotland), with a view that they will align with objectives in the future.

8.8 Research critique and further lines of enquiry.

This section acknowledges the limitations of the study and suggests further lines of enquiry.

This study was geographically focused on EU and UK waste and resource management policy. However, both waste and resource management and the transition to the circular economy requires a global perspective and international implementation. In focusing on EU policy, this study has assessed what is considered best practice with respect to supranational environmental policy. However, consideration of other internationally important (re: unsustainable consumption) nations, such as China, India and USA, could provide a more varied insight into the contribution of waste and resource management to the transition to the circular economy, both now and in the future. Furthermore, additional examples of good practice and different barriers could be identified. Looking further afield, assessment of emerging and developing nations could provide an altogether different perspective, one that is not currently locked-in with respect to conventional waste management strategies and technologies.

Similarly, the focus on UK waste and resource management policy has provided the perspective from a developed, northern European nation. Concerning EU policy, the UK can be considered as middle of the pack, lacking the progressive policies of leading member states such as Germany and the Netherlands but assimilating EU policy at a greater level than other member states, such as Greece and Italy. Again, assessment of other member states could provide a greater insight into the success of overarching EU policy and be used to identify examples of good and bad practice.

Another limitation concerns the sources of data used, e.g. specific documents, survey respondents and workshop participants. The document analysis used to compare the four home nations of the UK focused solely on waste and resource management strategies. However, it is acknowledged that in the transition to the circular economy, efforts should be made to bring together different sectors, departments and industries. Therefore, to assess fully the alignment of each home nation to the circular economy as a whole, strategy documents from other departments should also be included, and the integration of strategies between the departments reflected upon. Furthermore, as noted by Reike et al. (2018), it is common to find within circular economy literature the use of identical terms with different meanings. In this analysis, terms were found to have unclear meanings, particularly when considering the waste hierarchy. For example, incineration was often referred to without specifying whether it was “with -” or “without energy recovery”. This is of particular importance, with the former being classified as a recovery term and the latter a disposal term. Other terms were found to cross the boundaries of R-imperatives, for example, reuse could be classified under “Reduce” or “Preparation for reuse”. While efforts were made to decipher the correct meaning of terms from their context and / or position within the text, this has been acknowledged as a limitation of the circular economy framework.

With respect to the survey respondents and workshop participants, as this study focused on waste management professionals from industry and academia, an element of bias could be introduced. This is particularly true when introducing the concept of circular economy readiness, where the participants could have already bought into the idea before the workshop itself. Therefore, it is essential, if the concept is to be developed further, that opinions from contrasting industries and sectors are included.

The implications and limitations of this study highlight several promising gaps that could be addressed by further research.

(1) This study compared the waste management strategies of the four home nations of the UK against circular economy principles. As the circular economy should be implemented across a range of sectors, this study could be expanded to include a broader range of documents as to include a greater selection of sectors and industries. Strategies of particular importance would be those concerned with industrial strategy, environmental protection and social policy. This approach could also be applied to updated waste and resource management strategies, in order to assess long-term performance and levels of improvement.

(2) In the current study, the application of the readiness concept to the circular economy was completed using the waste and resource sector as an example. Future research could focus on other industries and sectors or engage with other stakeholders within the waste and resource management sector. Future research could also develop the concept of circular economy readiness further, by exploring the different potential aspects of readiness, i.e. technological / social / integrated, and by developing a range of indices or metrics that could help transform the concept into implementable action.

(3) This study considered environmental policy developed at an EU level and implemented by the UK, a developed, northern European nation. In addition, this study has acknowledged the differences between developed and developing nations in terms of consumption and waste and resource management policy. Future research could consider factors that influence environmental and sustainability policy implemented in developed and developing nations and use the differences to inform development-level specific actions to enable the transition to the circular economy. Such research could also be fed into the concept of circular economy readiness.

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Appendix 1: Thesis outputs

Poster presentations:

“In the search for effective waste policy: alignment of UK waste strategy and the EU circular economy package.” SciEng Research Symposium, Manchester Metropolitan University. September 2017

“Talking Rubbish! Expert opinion regarding the introduction of the Landfill Tax (Qualifying Fines) Order 2015 and determination of classification using the Loss on Ignition test.” SciEng Research Symposium, Manchester Metropolitan University. September 2017

Oral presentations:

“In the search for effective waste policy: alignment of UK waste strategy and the EU circular economy package.” – Fletcher, C. A. and Dunk, R. M. International symposium on waste management and landfill issues 2017, Sardinia. October 2017

“Unintended consequences of secondary legislation: A case study of the UK Landfill Tax (Qualifying Fines) Order 2015.” – Fletcher, C. A., Hooper, P. D and Dunk, R. M International symposium on waste management and landfill issues 2017, Sardinia. October 2017 (Nominated for the Luigi Mendia Award for the best paper on waste management policy.)

“A review of end of waste criteria and its application to MSW-derived incinerator bottom ash.” – Fletcher, C. A., Randviir, E. P., Banks, C. E. and Dunk, R. M. International symposium on waste management and landfill issues 2017, Sardinia. October 2017

“Waste regulation standards and their impact on the behaviour of waste managers.” Celebrating SEEG, October 2017

“Finding the solution to plastic pollution: Reducing plastic use in the Heaton’s.” Sustainable living in the Heaton’s, AGM, Heaton Norris. March 2018

“Transition to the circular economy: Contribution and ‘readiness’ of the waste management sector.” – Fletcher, C. A and Dunk, R. M. Waste and Resources Management Conference (WaRM 2018), Open University, Milton Keynes. June 2018 (Awarded for best presentation at WaRM 2018).

Appendix 2: Fletcher and Dunk, 2018

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CISA

IN THE SEARCH FOR EFFECTIVE WASTE POLICY: ALIGNMENT OF UK WASTE STRATEGY WITH THE CIRCULAR ECONOMY

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ABSTRACT

Over-consumption within a linear economy has been recognised internationally as a barrier to sustainability and a major cause of environmental degradation and economic disparity. To address these issues, the transition towards a circular economy (CE) has been advocated. A broad resource efficiency concept, the CE seeks to reduce consumption, encourages the reuse and recycling of materials and products, and encompasses the three pillars of sustainable development; economic prosperity, environmental protection, and social equity. Efforts to implement the CE have seen the introduction of various hierarchies that prioritise the implementation of R-imperatives (such as the '3Rs' of reduce, reuse, recycle). One such example is the waste hierarchy, originally introduced to encourage sustainable waste management and more recently reiterated by the EU Circular Economy Package as a means to stimulate the transition to the CE. Following the development of a CE Framework, this study presents a content analysis of the waste strategies of the four devolved nations of the United Kingdom. Key differences and similarities in the strategies of the four devolved nations are identified and discussed in light of CE aims, core concepts and principles (with particular focus on promotion of the waste hierarchy), enablers, and stakeholder engagement, where Scotland and Wales were found to have the most progressive strategies. This study also considers the potential impact of Brexit, where it is recommended an overarching UK-wide strategy that provides consistent and collaborative long-term objectives is required to replace the overarching objectives previously supplied by the EU policy.

1. INTRODUCTION

Rising global population and a growing trend towards higher living standards have led to increased depletion of natural resources and environmental degradation due to the linear 'take-make-dispose' model on which economic growth has been built (Moreno et al.,, 2016; Wysokinska, 2016). The need to overcome this unsustainable pattern of consumption has been acknowledged internationally, most notably through the prioritisation of Sustainable Consumption and Production (SCP) within the United Nations 10-year Framework of Programmes (UNEP, 2015), where a key component of SCP is the transition to a Circular Economy (CE).

At its core, the CE is a broad resource efficiency concept (Su et al.,, 2013) that seeks to mimic natural biological systems by continuously recirculating and reprocessing materials and energy (Lieder and Rashid, 2016). As discussed by Winans et al., (2017), the CE model has evolved continuously since the 1970s, building on and encompassing a number of preceding ideas. It is deeply rooted in resource efficiency concepts that advocate moving from end-of-pipe solutions to life cycle and systems thinking. For example, Stahel and Reday-Mulvay's (1976) vision of a 'loop economy' that returns durable products from cradle-to-cradle, and Pearce and Turner's (1990) argument for a shift from a 'resources-products-pollution' to a 'resources-products-regenerated resources' mode. Additionally, it includes the recognition that there are limits to growth (Meadows et al., 1972), and that human industry relies on resources and services provided by the biosphere (industrial ecology) and cannot therefore be considered in isolation from it (Erkman, 1997). Indeed, Murray et al., (2017) argues that rather than promoting biomimicry, the CE should aim to "bio-participate" where actions take place within the existing biosphere.

Despite widespread agreement for the need to transition to a CE, a standardised definition of the CE (or understanding of what transition entails) has been lacking, where this has been attributed to both the evolving nature of the concept and the use of the concept by stakeholders from different disciplinary or industrial backgrounds (Kirchherr

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et al., 2017). Analysis of 114 definitions found that while the CE is often defined using hierarchies of R-imperatives (e.g. the 3Rs of reduce, reuse and recycle), the systemic change needed to implement the CE is frequently overlooked (Kirchherr et al., 2017). Furthermore, definitions are limited by insufficient linkages to other aspects of sustainable development, primarily focusing on economic prosperity followed by environmental protection, and with very limited consideration of social equity or future generations (Kirchherr et al., 2017). To address this shortcoming, Kirchherr et al., (2017) proposed a standardised definition of the CE as "an economic system that is based on business models which replace the 'end-of-life' concept with reducing, alternatively reusing, recycling and recovering materials in production/distribution and consumption processes, thus operating at the micro level (products, companies, consumers), meso level (eco-industrial parks) and macro level (city, region, nation and beyond), with the aim to accomplish sustainable development, which implies creating environmental quality, economic prosperity and social equity, to the benefit of current and future generations."

Intended to function as a fully regenerative closed ecological-economic system (Lieder and Rashid, 2016), resource use should be reduced by embedding R- imperatives at all stages of design, production, distribution and consumption (Su et al., 2013; Wysokinska, 2016). Thus, in addition to clean production techniques, maintaining the flow of materials and energy within the CE requires a combination of innovative product design, extended producer responsibility (EPR), new business models, and consumer behaviour change, and hence necessitates stakeholder engagement across the supply chain (EMF, 2015; Lieder and Rashid, 2016; Stahel, 2016; Su et al., 2016; Tukker, 2015; Wysokinska, 2016).

Eco-design and regenerative-design approaches play a critical role, where resources are either designed out through dematerialisation or can be readily regenerated at end of life, and where product and component lifespan is extended through increased durability, repairability, and the standardisation of components (Leider and Rashid, 2016; Wysokinska, 2016). Reuse and regeneration can be further enhanced through EPR and the implementation of reverse cycles within the supply chain, whereby products and materials are returned to the producer to be reused or reprocessed (EMF, 2015; Wysokinska, 2016). Product utility can also be increased by changing the business model in which products are sold and consumed or through consumer reuse (Stahel, 2016). Providing products through service agreements, such as pay-per-use, sees the producer retain responsibility and therefore incentivises resource efficiency and product utility above unit sales (Stahel, 2016; Tukker, 2015). With respect to consumer reuse, the emergence of the 'sharing economy', in which underutilised assets are shared (or re-sold) through peer-to-peer interactions within community-based (online) services, may not only enable more efficient use of products but also deliver economic and social benefits (Cherry and Pidgeon, 2018; Martin, 2016). However, the extent to which these benefits are realised is unclear, with concerns that the sharing economy may lead to increased overall consumption (Cherry and Pidgeon, 2018; Martin, 2016).

The transition to a CE is often viewed as synonymous with or requiring a movement towards 'zero-waste' (e.g. Ghisellini et al., 2016). Zero-waste (ZW) can be defined in various ways including ZW to landfill and ZW emissions to land, sea and air, but generally requires sustainable waste management and increased resource utility (Cole et al., 2014). However, while the two concepts are clearly complementary, they can be viewed as subtly different (Veleva et al., 2017), with implications for policy development for appropriate emphasis. For example, Veleva et al., (2017) argue that ZW approaches focus primarily on recapturing resources from waste streams, reducing consumption, and applying a life cycle approach to product design, whilst the CE extends beyond this by designing out waste and introducing innovative business models and collaborative platforms to continuously reuse materials. The CE also emphasises use of renewable materials and energy and places a stronger emphasis on return of biological nutrients to nature. As such, pursuing ZW might be viewed as incremental continuous improvement, whilst in comparison the CE could be seen as transformative.

Although there is strong agreement regarding the urgent need to shift to more sustainable patterns of consumption and production, limitations of the CE (as described above) and barriers to transition have also been identified. Jawahir and Bradley (2016) argue that while the socio-political dimensions and opportunities of the CE are being pursued and promoted, the technological challenges to implementation are often overshadowed, where they highlight the need to promote innovation and expand thinking to consider multiple, intersecting lifecycles. Similarly, Murray et al., (2017) highlight the risk of unintended consequences, where impacts are transferred due to over simplistic goals that are based on reductionist thinking and mathematical models. Andrews (2015) suggests that the transition towards the CE may be limited due to the presence of materials and products that are difficult to reuse or recycle and a lack of knowledge and understanding of relevant stakeholders. Likewise, Kirchherr et al., (2017) highlight that consumers, and their role as key enablers of the CE, are frequently neglected.

Thus, to aid transition to the CE, the challenge for policy makers is to engage with all stakeholders to reduce consumption, enable and develop new markets, encourage innovation, and promote resource efficiency (Price, 2001; EMF, 2015; Lieder and Rashid, 2016). Three levels of contributing stakeholders should be acknowledged in successful CE policy; micro-level such as individual consumers, designers and producers; meso-level, including community groups, individual sectors and industrial parks; and, macro-level, encompassing cities and regions (including local authorities, national government and regional administrations), co-operative networks and multi-national businesses (Su et al., 2016; Kirchherr et al., 2017). Nevertheless, some have argued that the most important role of overarching strategies and policies is to engage and inspire individuals to consume less, reuse goods, and present high quality recyclate when waste is unavoidable (Price, 2001; EMF, 2015).

As previously noted, the R-imperatives are recognised as a building block of the CE, where ranking these imperatives (in order of preference for value retention) within R-hierarchies is viewed as necessary to provide guidance and promote effective implementation of the CE (Kirchherr et al., 2017; Murray et al., 2017). However a recent review of CE literature found significant variation in the number of R-imperatives used (between 3 and 10), the combination of imperatives, choice of terminology, and assigned meanings (38 different R-imperatives were identified with varying definitions), whether or not the imperatives were ranked, and in cases where they were ranked, their relative position (Reike et al., 2018). While efforts have been made to develop nuanced hierarchies employing a high number of R-imperatives, thereby providing an operationalisation principle than maximises resource value retention, inconsistencies remain (Potting et al.,, 2017; Reike et al.,, 2018). Nonetheless, as argued by Kirchher et al., (2017), without the use of R-hierarchies that explicitly identify waste prevention imperatives as the highest priority, the concept of CE could be subverted, resulting in limited and minimal changes when implemented. Furthermore, the introduction of strategies that address current (lower) priorities can lead to 'lock-in', where they lack the flexibility to change in the future and so the emergence of more sustainable strategies is restricted (Foxon, 2002). Perhaps one of the most consistent expressions of an R-hierarchy is the "waste-hierarchy" (4R-imperatives of reduce, reuse, recycle, recover, followed by dispose), introduced as a tool to promote sustainable waste management (Van Ewijk and Stegemann, 2014) and referenced in the definition of the CE proposed by Kirchherr et al., (2017). This hierarchy has been particularly visible over the last ten years, where continual development of European Union (EU) waste policy has repeatedly reiterated the waste hierarchy, including re-casting it as a tool to promote the CE within the EU Circular Economy Package (CEP).

This paper examines the circularity of current waste strategy within the UK. As the UK is currently a member of the EU, a brief review of EU waste policy is presented first, followed by current waste policy in the UK and the potential impact of Brexit. Using an adapted CE-framework, a content analysis is then conducted to assess and compare the four devolved nations in terms of CE aims, core concepts and principles (with a focus on use of the waste hierarchy as an operationalisation principle), enablers, and stakeholder engagement.

1.1 Abbreviations

CE: Circular Economy
CEP: Circular Economy Package (EU)
EFTA: European Free Trade Association
EPR: Extended producer responsibility
EWSR: European Waste Shipment Regulations
EU: European Union
SCP: Sustainable Consumption and Production
ZW: Zero waste

2. CONTEXT

2.1 EU Circular Economy Package

Already a leader in environmental policy (Wysokinska, 2016), the adoption of the CEP by the EU will introduce new priorities that advocate resource efficiency and initiate the transition towards a CE (EC, 2017). While previous strategies such as the 'Roadmap to a resource efficient Europe' (2011-2013) and 'Towards a circular economy: a zero-waste programme for Europe' (2014-2015) promoted the CE, their emphasis remained on the efficient use and management of waste. In contrast, the CEP aims to prioritise the CE and address inherent limitations of previous policy initiatives, including a shift in focus toward full product lifecycle thinking (EC, 2017). Although the CEP does encourage industrial symbiosis and the development of secondary materials markets, it also retains an emphasis on waste management strategies such as reiterating the need to implement the waste hierarchy and revising targets for landfill diversion and recycling (Table 1; EC, 2017; Pomberger et al., 2016).

While full implementation of the waste hierarchy would align with CE ideals, Van Ewijk and Stegemann (2014) and Gharfalkar et al., (2015) argue that the limited specification of prevention, the absence of a distinction between open- and closed- loop recycling, and the lack of inclusion of other sectors could constrain dematerialisation and resource effectiveness. Other authors have also argued that too little emphasis is placed on the higher priority R-imperatives. For example, while reducing waste at source is the most effective and efficient CE strategy, the absence of quantitative targets for reduction or reuse can create a perceived policy bias towards recycling and disposal (Mazzanti and Zoboli, 2009; Fischer, 2011). However, it is noted that the CEP is supported by other initiatives such as the "Thematic Strategy on the Sustainable Use of Natural Resources" (EC, 2005), the "SCP Action Plan" (EC, 2008) and the "Integrated Product Policy", which includes elements such as eco-design, eco-labelling, and green public procurement (EC, 2016). In combination, these approaches aim to reduce the environmental impact of resource use while promoting economic growth through improving the environmental performance of goods and services across the full lifecycle and creating sustainable business opportunities (EC, 2005, 2008, 2016). This provides a framework of strategies and policy objectives that individual member states should adhere to, to aid their transition toward a CE.

2.2 Current UK waste policy

The multilevel governance character of the EU sees overarching objectives published centrally, with decisions regarding the approaches and instruments used to achieve these objectives resting with the individual member states (Nilsson et al., 2012). There are several reported techniques by which EU policy is transposed into national policy including "copy-out" (using the exact words and phrasing of the EU directive), "gold-plating" (going beyond the minimum stated requirements), and "no gold-plating" (consists of only the minimum requirements; Anker et al., 2015). This degree of member state discretion has led to significant

TABLE 1: Current EU waste management targets and the proposed amendments set out in the Circular Economy Package (CEP).

Waste Stream	Existing Policies and Targets		Circular Economy Package Proposals	
Municipal Solid Waste	**Landfill Directive (EC, 1999)** When compared to 1995 base year, the share of biodegradable municipal waste going to landfill may not be greater than 75% by 2006, 50% by 2009, and 35% by 2016.		**Proposed Amendment (EC, 2018b)** Bans disposal to landfill of separately collected wastes and extends landfill diversion target to all municipal waste, where the share of municipal waste sent to landfill is limited to 10% by 2035.	
	Waste Framework Directive (EC, 2008) By 2015, separate collection shall be set up for at least paper, metal, plastic and glass. Preparing for re-use and recycling of 50% of at least paper, metal, plastic and glass from household and similar sources by 2020.		**Proposed Amendment (EC, 2018d)** Extends preparation for re-use and recycling to all municipal waste, with targets of 55% by 2025, 60% by 2030, and 65% by 2035.	
Construction & Demolition Waste	**Waste Framework Directive (EC, 2008)** Preparing for reuse, recycling and other recovery such as backfilling of 70% of non-hazardous construction and demolition waste by 2020.		**Proposed Amendment (EC, 2018d)** No extension to existing target, but requires introduction of measures to promote selective demolition and removal of materials, and to establish sorting systems for at least wood, mineral fractions (concrete, bricks, tiles and ceramics, stones), metal, glass, plastics and plaster.	
Packaging Waste	**Packaging Waste Directive (EC, 1994)** By 2008 60% of packaging waste to be recovered, with a minimum of 55% and maximum of 80% to be recycled, and minimum recycling rates for specific materials as follows:		**Proposed Amendment (EC, 2018c)** Removes the maximum and extends the minimum recycling rates for all packaging waste to 65% by 2025 and 70% by 2030, and extends the targets for specific materials as follows:	
	wood:	15%	wood:	25% and 30%
	plastics:	22.5%	plastics:	50% and 55%
	metals:	50%	ferrous metals:	70% and 80%
			aluminium:	50% and 60%
	glass:	60%	glass:	70% and 75%
	paper and board:	60%	paper and board:	75% and 85%

differences in national implementation of resource and waste policy (Garcia Quesada, 2014).

Over the last two decades, UK environmental legislation has been largely shaped by EU directives, where it is a notable feature of UK waste policy that secondary legislation is used extensively to transpose EU law into domestic law (Scotford and Robinson, 2013). Indeed, EU legislation has provided momentum to improve waste management in the UK, lifting it above the national party politics that previously hindered the development and implementation of a long-term strategy (UKELA, 2016; BP Collins, 2016). During this time, the UK has introduced fiscal instruments such as the landfill tax, extended separate recyclate collections, and increased exports of refuse derived fuel, all of which have aided a transition away from high landfill dependency (Pomberger et al., 2016). However, due to a plateau in progress potentially caused by the "no gold-plating" approach of transposition, the development of new measures that manage resources rather than waste are now required to maintain the momentum of positive change.

2.3 Impact of Brexit

Although the UK is currently negotiating its withdrawal from the EU (termed "Brexit"), it is expected that the CEP will be transposed into UK law. Once the UK has fully withdrawn from EU membership it will no longer be obligated to transpose or adhere to EU directives. However, while the official withdrawal date is the 29th March 2019, a transition period extending to 31st December 2020 has recently been agreed, during which EU law "shall be applicable to and in the UK" (EC, 2018a). Hence, as the amendments to existing directives proposed under the CEP (EC, 2018b-d) are expected to enter into force in 2018 and require transposition within eighteen months, the UK will be obligated to transpose them. As noted above, current UK environmental law is highly dependent on that of the EU, where the UK will convert the existing body of EU environmental law into domestic law on 'exit day' through a blanket transposition under the Withdrawal Bill (European Union (Withdrawal) HL Bill (2017-19) 79). However, after the end of the transition period the UK would not be obligated to adhere to the CEP, where UK governments could act to repeal or amend the transposed domestic law (BP Collins, 2016; UKELA, 2017). This leads to the question of how UK waste and resource management will develop in the absence of the long-term vision and strategy provided by the EU. Current commentary on post-Brexit waste policy suggests that in the short term the UK would continue to apply existing EU legislation and strategy (Burges Salmon, 2016; BP Collins, 2016). However, in the medium to long term it is difficult to predict whether successive UK governments would maintain compliance with current and successive EU legislation, look to go beyond them, or maintain the current status quo, with the risk of being left behind (Burges Salmon, 2016).

Other potential implications of Brexit for waste management in the UK and for other EU member states have also been highlighted, particularly in relation to cross border movement of wastes (House of Lords, 2017; UKELA, 2016, 2017). Gibraltar (a British overseas territory) is completely reliant on Spain for its waste management (both collection and treatment) and the Republic of Ireland exports 40% of its hazardous waste to the UK due to the lack of capacity in local treatment facilities (McGlone, 2018). The UK also exports a significant tonnage of waste derived materials to other EU member states. Indeed, exports of waste derived fuel to European countries have increased from zero in 2010 to over 3 million tonnes in 2016 (DEFRA, 2017; UKELA, 2016). Likewise, due to limited domestic processing capacity, exports of recyclable materials have risen from around 8 million tonnes in 2002 to around 14 million tonnes in 2015 (DEFRA, 2017), where around a quarter of sorted waste materials are sent to northern European countries which have an overcapacity in processing facilities (House of Lords, 2017).

Post-Brexit, the movement of waste between the UK and EU countries must adhere to the European Waste Shipment Regulations (EWSR) (EC, 2006). Under the EWSR, the import of waste is allowed from a third (non-EU) country that is a party to the Basel Convention on the Control of Transboundary Movement of Hazardous Wastes and their Disposal (the Basel Convention) (UNEP, 1989). However, export of waste for disposal or mixed municipal waste for recovery to a third country is prohibited, unless it is both a party to the Basel Convention and a member of the European Free Trade Association (EFTA). Furthermore, imports and exports of waste between the UK and the EU will most likely become subject to border checks and depending on the outcome of negotiations could become subject to tariffs (EC, 2018a), with the risk that such shipments become financially unviable (House of Lords, 2017).

The future status of the UK with respect to the Basel Convention (an international agreement ratified jointly by the EU and the UK) is uncertain. Analysis indicates that the effect of Brexit on such "mixed agreements" is somewhat ambiguous, with some analysts concluding that they will have to be renegotiated, and others adopting the position that the UK will remain bound by them post-Brexit (UKELA, 2017). Nonetheless, while the status of mixed agreements remains to be clarified, the UK government has expressed the view that the UK is a party in its own right and will continue to be bound by such agreements post-Brexit (House of Lords, 2017).

The UK joining the EFTA post-Brexit has been posited as a potential option, in which case waste exports from the EU to the UK could continue with respect to EWSR, however access to the single market (so as to avoid import/export tariffs) would require the UK to continue to adopt the relevant evolving EU acquis. Furthermore, for any recovery of waste generated by EU member states and exported to the UK, the EU member state will only be able to count that waste towards fulfilment of EU targets if the treatment conditions are equivalent to the requirements of applicable EU directives (EC, 2018d).

All of the above Brexit related uncertainties regarding the future of waste management in the UK are further complicated by the differing positions of the devolved nations. The devolution of power in the UK allows the four home nations (England, Scotland, Wales and Northern Ireland) to manage waste and resources within their own boundaries while contributing to overall UK objectives. This has led to the introduction of different strategies by the four nations. Indeed, based on an evaluation of primary and secondary environmental legislation, Scotford and Robinson (2013) argue that Wales and Scotland are providing the most innovative legislation developments within the UK.

3. METHODS

A content analysis was used to assess the current waste management strategies of the four devolved administrations of the UK home nations. Based on a CE framework adapted from Kirchherr et al., (2017) in light of the literature reviewed above, the main themes explored within the analysis were; CE aims, core concepts and principles, enablers, and stakeholder engagement, with a particular focus on the promotion of the waste hierarchy as an operationalisation principle and the inclusion of stakeholders. The analytical framework is presented in Figure 1, where the correspondence between the waste hierarchy and a more nuanced hierarchy of R-imperatives is presented in Figure 2. Here the R-hierarchy is synthesised from Potting et al., (2017) and Reike et al., (2018), and modified to align with the EU waste-hierarchy, such that repair without change in ownership (by a consumer or under a product-service agreement) to extend product life is viewed as a waste prevention measure (as the product is not discarded and has not become a waste). The role of re-servitisation and re-modelling business and actions that can be undertaken by consumers (italic text) as enablers of high priority R-imperatives are also highlighted.

Content analysis has been widely employed as both a qualitative and a quantitative method across a range of policy areas including: health (e.g. Lemiengre et al.,, 2008), environment (e.g. Maczka et al.,, 2016), serious crime (e.g. Paoli et al.,, 2017), procurement (e.g. Testa et al.,, 2016), and cleaner production (e.g. Peng and Liu, 2016). It provides a simple yet flexible method to describe and quantify phenomena, analyse written, verbal or visual communication, and enhance the understanding of data through the exploration of theoretical ideas (Elo and Kyngäs, 2008). It also allows the inclusion, comparison and corroboration of large volumes of textual data from different sources (Elo and Kyngäs, 2008). To do this and ensure reliability, analysis should be objective, systematic and quantitative whereby categories of analysis are precisely defined, and the inclusion/exclusion of documents is based on consistent rules (Testa et al.,, 2016).

Taking these factors into account, the most recent waste management strategies published by each of the home nations were selected for inclusion in this study:

- England: "Waste Management Plan for England" (DEFRA, 2013);
- Scotland: "Scotland's Zero Waste Plan" (Natural Scotland, 2010);
- Wales: "Towards Zero Waste - One Wales: One Planet" (WAG, 2010);
- Northern Ireland: "Delivering Resource Efficiency" (DoE, 2013).

Only main body text was analysed with all other text (front matter, legends, footnotes, etc.) excluded. To ensure rigour, two researchers assessed all documents, with points of ambiguity or disagreement discussed and clari-

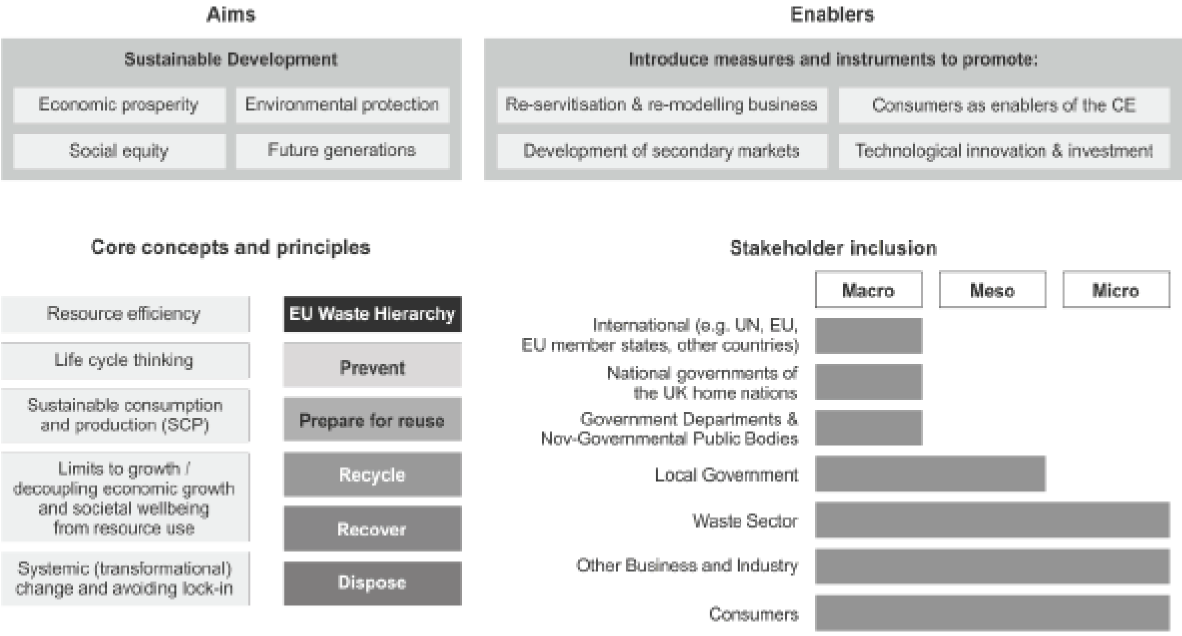

FIGURE 1: Circular Economy Framework (adapted from Kirchherr et al.,, 2017).

fied. The use of CE or ZW terminology, the broader context within which waste management was positioned, and the overarching approach of each strategy document was first explored. This was supported by the compilation of national statistics regarding population and rates of waste generation, recycling and landfilling (based on DEFRA, 2018). Using a basic automated keyword search, and manual analysis to ensure complete coverage, the inclusion of CE aims, core concepts and principles, and enablers was evaluated (Corbin and Strauss, 2008; Welsh, 2002). Waste hierarchy R-imperatives and stakeholder terms were also quantified on both a total document and per paragraph basis, and documents ranked (based on per paragraph counts) to compare incorporation of waste hierarchy R-imperatives and stakeholder engagement. Additionally, the responsibilities of each stakeholder group were noted and compared.

4. RESULTS AND DISCUSSION

4.1 Context and overarching vision

Table 2 presents a summary of the waste strategy document for each home nation, including the volume of text analysed, the context, and the overall vision, alongside population and waste statistics for the document year and for 2016 (Defra, 2018).

4.1.1 England

The stated aim of the Waste Management Plan for England is to work towards a ZW economy as part of the transition to a sustainable economy. Here, a ZW economy is defined as one within which material resources are reused, recycled or recovered wherever possible and only disposed of as the option of last resort, where the need to reduce waste generation and ensure all materials are fully valued during their productive life (in addition to at end of life) are also recognised. However, the substance of the plan focuses primarily on minimising the environmental and human health impact of waste generation and management, where this is achieved by supporting local authorities (and waste management companies) to prioritise recycling and recovery of waste materials. While it highlights the role of ZW initiatives and advocates lifecycle thinking and closed loop approaches, it provides little more than rhetoric regarding these ideas. For example, although it does imply that resources should be used efficiently, rather than introducing governmental drivers to achieve this, it places the responsibility on business and industry for creating more goods and services with fewer resources.

4.1.2 Scotland

Scotland's Zero Waste Plan defines a ZW Scotland as one that makes the most efficient use of resources by minimising demand on primary resources and maximising the reuse, recycling and recovery of resources instead of treating them as wastes. It frames waste management strategy within the context of economic growth and climate change, where resources are managed efficiently, economic opportunities are sought (and capitalised upon), waste materials are given a value, and greenhouse gas emissions are reduced. To do this, it advocates a transition away from a linear economy, long-term policy stability, and effective resource use. It also acknowledges the role of consumer behaviour, asking individuals and businesses to recognise and take responsibility for their actions. It recognises the need for continued waste management strategies for the foreseeable future and promotes the reuse, recycling and recovery of resources from waste in line with the waste hierarchy.

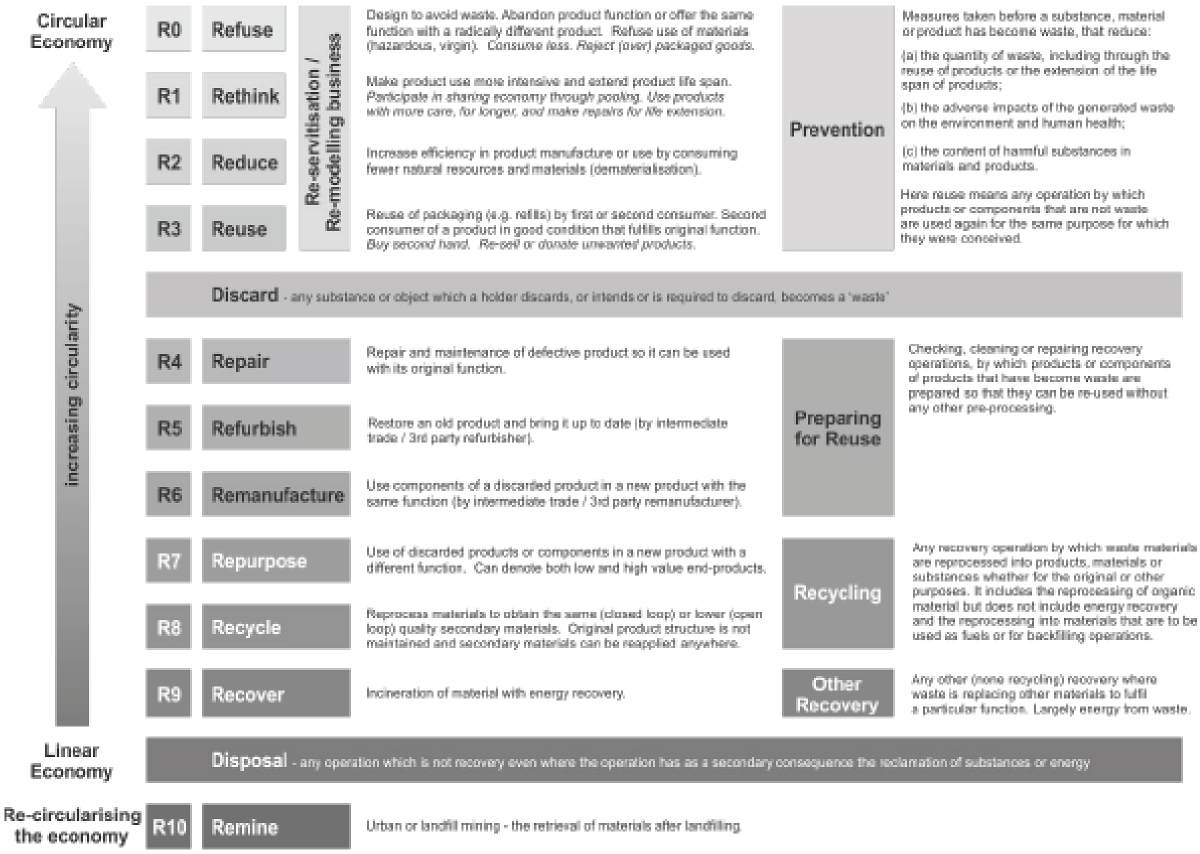

FIGURE 2: Alignment of the EU Waste Hierarchy with the R-Imperatives (R0 – R10) needed in the transition to the circular economy (R-imperatives synthesised from Potting et al.,, 2017 and Reike et al.,, 2018).

4.1.3 Wales

Towards Zero Waste – One Wales: One Planet defines ZW as an aspirational end-point where all waste that is produced is reused or recycled as a resource, without the need for any landfill or energy recovery. It frames waste management strategy in the broader context of social justice, cultural legacy, climate change and limited resources. It aims to create a pathway to where resource use is within environmental limits, society and culture prosper, and human well-being is maximised. To do this, it advocates SCP, optimisation of material utilisation, and reduced dependence on primary resources. It promotes a long-term framework that requires the engagement of citizens, business and industry. Citizens are asked to rethink and reconsider consumption patterns, and to become a recycling society, whilst business and industry are asked to use alternative materials, employ Integrated Product Policy and reduce associated emissions. It acknowledges the continued production of some waste and so advocates enhanced action on waste prevention, maximised recycling and near ZW to landfill. It also notes the requirement to manage legacy wastes.

4.1.4 Northern Ireland

The Delivering Resource Efficiency strategy aims to set a direction towards treating waste as a resource and using it more efficiently. This is positioned within the EU objective of moving towards a CE, and although no definition of a CE is given, it is noted that it requires a greater focus on waste prevention followed by an increase in recycling. The strategy is positioned in the context of economic growth, whereby sustainable waste management can promote green jobs, maximise opportunities, and contribute to a low carbon, CE It identifies the need for both socially responsible economic growth and global economic transformation to address depletion of finite natural resources and climate change. To do this, it advocates the implementation of the waste hierarchy, recognition of waste as a resource, use of environmentally friendly technology and behaviours, and increased integrated support across sectors and between stakeholders.

4.2 CE aims, core concepts and principles, enablers and stakeholders

Development of the CE framework allowed the systematic, yet simple, assessment of documents. When CE aims, core concepts and principles (including promotion of the waste hierarchy), enablers, and the inclusion of stakeholders were considered, both similarities and substantial differences were found between the waste strategies of the UK home nations.

TABLE 2: Summary of UK home nations population, waste generation and management statistics, and national waste strategy documents.

	England		Scotland		Wales		Northern Ireland	
Year of statistics	**2013**	**2016**	**2010**	**2016**	**2010**	**2016**	**2013**	**2016**
Population	53.9m	55.3m	5.3m	5.4m	3.0m	3.1m	1.8m	1.9m
Waste generation(i)	400 kg	410 kg	490 kg	440 kg	450 kg	420 kg	430 kg	450 kg
Recycling rate	44.2%	44.2%	32.5%	42.8%	44.0%	56.7%	41.5%	43.0%
Landfill rate(ii)	25%	21%	41%	30%	33%	16%	24%	27%
Strategy document	**Waste Management Plan for England**		**Scotland's Zero Waste Plan**		**Towards Zero Waste One Wales: One Planet**		**Delivering Resource Efficiency**	
Total pages	42		59		92		68	
Pages analysed	38		46		59		51	
Paragraphs analysed	194		288		357		374	
Words analysed	10,943		13,746		13,768		19,604	
CE Terminology	zero waste		zero waste		zero waste		circular economy	
Context	Minimise environmental & human health impacts		Economic growth & addressing climate change		Social & cultural justice, climate change & limited resources		Economic growth	
Approach	Supports local authorities, highlights zero waste initiatives, and advocates lifecycle thinking		Advocates long-term policy stability and effective resource use, acknowledges role of consumer behaviour and notes need for continued waste management		Highlights that resource use should be within environmental limits. Engages citizens, business & industry, and notes legacy wastes		Advocates implementation of waste hierarchy, recognises waste as a resource, and calls for increased integration and support across sectors and stakeholders	

(i) Municipal waste generation per capita per year (ii) Biodegradable municipal waste disposed to landfill as a % of the 1995 baseline.

4.2.1 CE aims

All four documents made reference to economic prosperity combined with some other dimension(s) of sustainable development, variously referring to a 'zero waste economy' and a 'sustainable economy' (England, Scotland and Wales), a 'low carbon economy' and a 'green economy' (Scotland, NI) and a 'prosperous society' characterised by full employment and high value green jobs (Wales). However, the extent to which environmental quality, social equity, and future generations were considered varied significantly.

With respect to environmental issues, all four documents referred to environmental protection, with a strong emphasis on reducing climate change impacts. Regarding environmental targets and ongoing assessment of strategies, Scotland and Wales were the most progressive, going beyond the weight-based indices used within EU policy by adopting more challenging targets measured a carbon footprint based metric (Scotland) and ecological footprinting (Wales). While NI mentioned carbon footprinting, like England it did not introduce any new targets or metrics to measure improvements.

While all four documents referred to safeguarding human health, and Scotland and NI made some reference to social benefits and well-being, the emphasis was less than that placed on environmental protection. Wales was the only exception to this, with directly comparable prominence of environmental and social aspects of the CE, , linking economic and social development with environmental quality, well-being, social justice and equality of opportunity.

All four documents made some reference to shaping the future (through decisions made now) and/or future waste management needs, where Scotland, Wales and NI also made specific reference to future generations. Wales had the strongest consideration of future societal needs (as indicated by the title of the strategy document), where the concept of living within environmental limits explicitly incorporates the time dimension so as to ensure sufficient resources are available to achieve a better quality of life for both present and future generations.

4.2.2 Core concepts and principles

All four documents included multiple references to resource efficiency, where the emphasis placed on this concept was comparable across Scotland, Wales and NI, but significantly weaker for England. Scotland and Wales clearly identified the need for large-scale changes to achieve their objectives (including changes to attitudes and behaviours, and acceptance of change), highlighting the role of policy and the public sector in driving this change. In comparison, NI made limited reference to the scale of change (although the need for behavioural change and the role of Government leadership in maintaining the pace of change were touched on), while England made no reference to the scale or type of change needed. Inclusion of other core concepts was variable and limited. Only England and NI made explicit reference to decoupling economic growth from resource use, only Wales recognised limits to growth, and only Wales and NI cited the need for SCP. While Wales and NI made multiple references to the need for life cycle thinking and approaches, England and Scotland made only one reference each. In the case of England this was simply to note that departure from the waste hierarchy could be justified by lifecycle thinking (rather than advocating lifecycle thinking as an underpinning concept to delivering resource efficiency).

4.2.3 Promotion of the Waste Hierarchy as an operationalisation principle

Figure 3 presents the occurrence of terms associated with waste hierarchy categories within the waste strategy documents of the UK home nations on both an absolute and per paragraph basis.

While occurrence of the waste hierarchy categories differed widely between the four documents on an absolute basis, frequency counts were more comparable on a per paragraph basis. Overall, the implementation of the full waste hierarchy across all documents is considered to reflect EU waste policy, with some differences in relative emphasis relating to the approach to transposition adopted by England and NI on one hand ("no gold-plating", reactive) and Scotland and Wales on the other ("gold-plating", proactive).

Recycling strategies (material recovery, anaerobic digestion, and composting) were dominant within all four documents, where this national policy emphasis on recycling is likely driven by EU policy and targets that focus on recycling and landfill diversion (Mazzanti and Zoboli, 2009; Fisher, 2011).

Prevention strategies were the second most frequently cited in all documents. It is noted that differences in the counts of prevention terms will to some extent reflect the scope of the waste strategies, where England and Scotland both elected to develop separate waste prevention plans and therefore provided only an overview of intended prevention activities within the analysed documents. Nonetheless, inferences can be drawn from the presence or absence of any reference to different prevention imperatives and activities. Furthermore, it is noted that the separate consideration of waste prevention strategies may have unintended consequences arising from a lack of joined up thinking between waste prevention and waste management activities.

The majority of the prevention terms counted made general reference to the need to reduce waste and mirrored the terminology employed by EU policy. While all four documents made some reference to activities associated with R0-R2 (Refuse, Rethink, Reduce), there was a much stronger emphasis on these imperatives in the Welsh document (particularly with respect to product design and the use of recycled materials), and this was also the only strategy to note the role of consumers (in buying less). Likewise, only Wales and Scotland included R3 (Reuse), and only Wales included re-servitising and re-modelling business. .

The least priority was given to "Recover" terms in all documents except Scotland (where it ranked fourth ahead of disposal). However, reference to incineration within the Scottish document was found to be in conjunction with a potential ban on incineration, where the context was to ensure strategies were moved further up the waste hierarchy (not just from disposal to incineration).

The use of continued disposal was found to be a higher priority for the English document (ranked third within this document) when compared with Wales and NI, where it ranked fourth and Scotland where it was given least priority. Interestingly, it is noted that when counts included reference to landfill diversion, the majority of mentions in the Scotland (77%), Wales (56%) and NI (59%) documents were with respect to the latter, whilst in the English document the majority of mentions (66%) were concerned the continued use of landfill.

As noted by Reike et al (2018) it is common to find within CE literature the use of identical terms with different meanings. In this analysis, particularly when considering the waste hierarchy, terms were found to have unclear

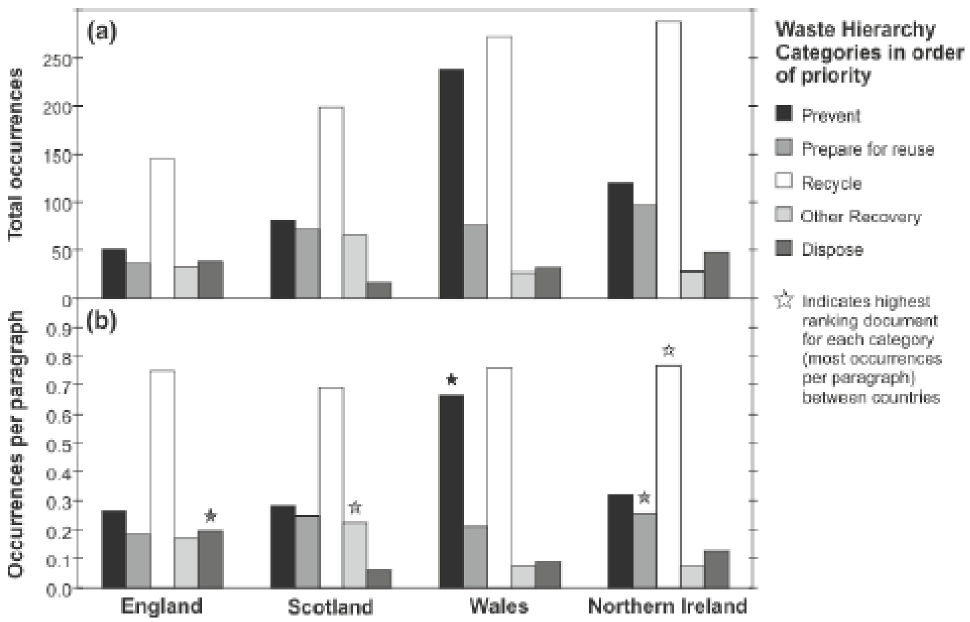

FIGURE 3: Representation of waste hierarchy categories in the waste strategy documents of the UK home nations on (a) a total occurrences basis and (b) an occurrences per paragraph basis.

meanings. For example, incineration was often referred to without specifying whether it was "with energy recovery" or "without energy recovery" with the former being classified as a recovery term and the latter a disposal term. Other terms were found to cross the boundaries of R-imperatives, for example reuse could be classified under "Reduce" or "Preparation for reuse". While efforts were made to decipher the correct meaning of terms from their context and / or position within the text, this has been acknowledged as a limitation of the framework.

4.2.4 Enablers and stakeholder engagement

Comparison of the four documents found variation in the dominant types of enabling measures and instruments employed to drive market changes. While all four documents made some reference to investment, other fiscal incentives/disincentives, green procurement, extended producer responsibility, and the use of voluntary agreements and standards, the relative emphasis differed. Scotland had a strong emphasis on investment, England dominantly referred to EPR followed by investment, Wales promoted the use of green procurement followed by EPR, while NI focused on voluntary agreements / standards and EPR. Furthermore, Wales, and to a lesser extent Scotland and NI, encouraged the development of markets for recyclates and reuse. With respect to measures that addressed consumer behaviour, England was found to be severely lacking. In comparison, Scotland, Wales and NI all promoted the use of education, communication, and consumer engagement and awareness campaigns to change attitudes. These strategies also incorporated measures that required the involvement of other sectors as well as the waste management industry.

Figure 4 presents the occurrence of terms associated with stakeholder categories within the waste strategy documents of the UK home nations on both an absolute and per paragraph basis, where the responsibilities identified for each stakeholder group with respect to policy instruments and feedback mechanisms are summarised in Tables 3-6 for each of the home nations.

Substantive differences were found between the four documents with respect to the engagement of different stakeholder groups. While, England and NI tended to focus on Macro-level stakeholders, particularly those concerned with cities and regions, Wales and Scotland also placed equal emphasis on micro-level (e.g. consumers, producers, designers) and meso-level stakeholders (e.g. sectors, community groups). In light of the argument made by Su et al (2013), Wales and Scotland would be the most successful in implementation of the CE as they include all three levels of stakeholders.

Notable comparisons include the similar prominence of national stakeholders in all four documents. This is expected given the nature of the documents (i.e. published by the devolved governments and being primarily concerned with domestic strategy). While there was differing prominence, the responsibilities of GD/NGPB and International stakeholders were similar, reflecting the former's role as regulators to ensure compliance and issue sanction where necessary and the latter's role to provides and enforce overarching objectives and targets. With respect to international stakeholders, England and NI were found most likely to engage, this being due to existing waste export routes (England) and the presence of a land border with the Republic of Ireland together with ambitions of an all-island waste strategy in NI. Scotland and Wales also referred to using their influence with national and international stakeholders to shape future goals.

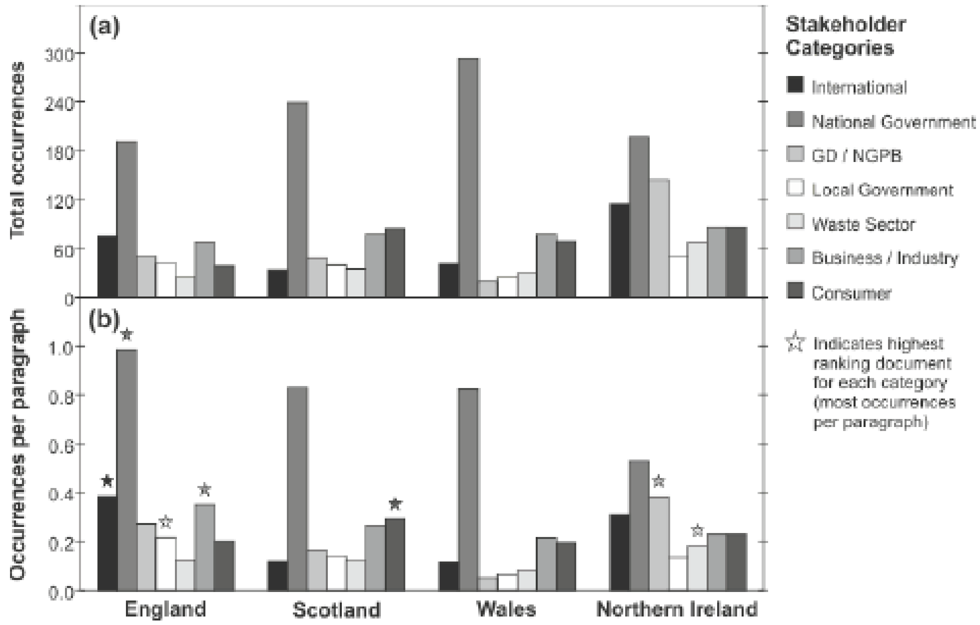

FIGURE 4: Representation of stakeholder categories in the waste strategy documents of the UK home nations on (a) a total occurrences basis and (b) an occurrences per paragraph basis.

TABLE 3: Stakeholder responsibilities within the Waste Management Plan for England.

Stakeholder	Responsibilities
International	Set overarching legislation and objectives. Introduce broad programmes to assist with meeting objectives. Require the collection of data to assess progress.
National	Transpose international legislation into national objectives. Set targets, provide support and guidance. Encourage sustainable thinking within resource and waste management. Produce quality standards for recycled materials. Identify suitable locations for future facilities. Monitor and review progress. Provide information and data to other stakeholders. Drive behaviour change
Government Departments & Non-Gov. Public Bodies	Implement international and national legislation and policy. Provide funding for schemes. Organise voluntary sector agreements. Distribute environmental permits. Conduct routine inspections. Provide advice and guidance on the of waste hierarchy strategies and support inter-stakeholder collaboration. Provide data and evidence regarding current and future waste management activities. Initiate and/or respond to consultations.
Regional	Obligated to implement national legislation, provide waste collection services, and support businesses in meeting their responsibilities. Work in partnership with the waste sector to ensure full and efficient waste services. Record and report waste data and illegal activity. Provide evidence to consultations.
Waste Sector	Adhere to national and international legislation and relevant environmental permit conditions. Where appropriate, develop actions to meet quality standards and change behaviours to contribute to national objectives. Obligated to provide waste collection services that are regular, efficient and affordable, working in partnership with local authorities and other regional stakeholders. Contribute to future waste strategy by providing evidence regarding current activities and responding to consultations.
Other Business & Industry	Adhere to national and international legislation, meet sector specific targets, participate in voluntary agreements, and provide private financial initiatives. Supported in recognising and capitalising on resource efficiency opportunities and encouraged to incorporate sustainable thinking into product/service design. Contribute to future waste strategy by providing evidence regarding current activities and responding to consultations.
Consumers	Provide evidence on current waste management activities and can respond to consultations. It is acknowledged that consumers are the main contributors to waste generation and that a change in behaviour would contribute to national objectives; however, they are not held responsible or accountable by any policy mechanism.

TABLE 4: Stakeholder responsibilities within Scotland's Zero Waste Plan.

Stakeholder	Responsibilities
International	Set overarching legislation and objectives. Introduce broad programmes to assist with meeting objectives. Promote the waste hierarchy and high-quality recycling. Require the collection of data to assess progress.
National	Introduce policies, targets and strategies to address the requirements of international legislation. Develop programmes, promote the waste hierarchy and best available techniques, introduce measures that value resources, and develop secondary materials markets. Provide guidance, tools and support to encourage good practice, and promote long-term stability, eco-design and investment. Stimulate behaviour change by strengthening market confidence, developing measures to influence behaviour, and providing reliable information. Information is collected and reviewed to measure progress with respect to targets and the success of implemented measures and initiatives.
Government Departments & Non-Gov. Public Bodies	Enforce regulatory frameworks and provide other regulatory functions to control relevant activities, develop programmes and tools, and provide guidance for the delivery of zero waste plans and policies. Enable efficient resource use. Encourage investment in innovative technologies. Contribute to the design of non-waste facilities / activities. Provide evidence to consultations and macro level studies.
Regional	Adhere to regulatory frameworks. Develop programmes and strategic waste infrastructure plans with neighbouring regions. Provide leadership in areas of influence and to achieve value for money with respect to procurement. Provide evidence for consultations, adhere to audits, report data, and contribute to relevant planning applications.
Waste Sector	Adheres to regulatory frameworks. Partial responsibility for compliance. Responsibility regarding investment in capacity and infrastructure considering national policy. Develop good practice commitments. Adhere to audits, and report information concerning compositional data, services provided, and voluntary opportunities. Increase workplace skills. Public engagement.
Other Business & Industry	Adhere to regulatory frameworks. Responsibility for investment in capacity and infrastructure considering national policy. Subject to sector-specific programmes. Adhere to good practice commitments. Develop innovative technologies. Responsibility for reducing waste generated under their control through resource efficiency opportunities and the incorporation of sustainable thinking into product/service design. Provide evidence to consultations. Participate in awareness campaigns. Improve understanding and usage of resources.
Consumers	Active participation in programmes and initiatives. Provide evidence to consultations. Involvement in waste infrastructure planning process. Increase understanding of consumption and waste generation. Recognise and take responsibility for the waste generated. Implored to be enthusiastic and take action.

Perhaps the starkest difference between the four documents was the inclusion of consumers, or lack thereof, where they held no responsibilities within the English document other than to receive waste management services and potentially participate in initiatives and information collection schemes. This contrasts with the Welsh and Scottish documents that, to varying degrees, hold the consumer responsible for their level of consumption and waste generation, and asks them to actively engage and participate in waste reduction programmes.

With respect to industry and business groups, Scotland and Wales encouraged greater engagement with CE ideals when compared to England and NI. Within the former, industry and business were asked to be innovative, and were encouraged to develop and take opportunities that would incorporate CE thinking into their business models. In contrast, in England and NI engagement with industry and business was limited to providing policy, regulation and voluntary agreements (these were present in all documents) to which business and industry should adhere. Interestingly, NI placed an emphasis on the role of business and the implementation of environmental management systems to

TABLE 5: Stakeholder responsibilities within Towards Zero Waste, One Wales: One Planet.

Stakeholder	Responsibilities
International	Set overarching legislation and objectives. Introduce broad programmes to assist with meeting objectives.
National	Transpose international legislation and objectives. Provide a long-term vision to reduce Wales' ecological footprint to within environmental limits. Apply key principles (precautionary principle, polluter pays principle, proximity principle, waste hierarchy, and equality of opportunity). Set domestic targets and sector-specific objectives. Introduce penalties for non-compliance. Grant powers to regulators for enforcement. Explore initiatives. Develop sector plans (including voluntary targets). Raise awareness. Provide advice and support regarding secondary materials markets, IPP, and waste infrastructure. Promote broader themes of zero-waste, sustainable development and citizen empowerment. Collect and publish data. Monitor indicators of progress (ecological footprint of waste, provision of recycling services, destination of recyclates, outcomes of eco-design programmes, wellbeing, employment, and skills).
Government Departments & Non-Gov. Public Bodies	Ensure and enforce compliance. Develop and implement campaigns. Support local capacity/infrastructure plans and skills development. Provide information on technical requirements. Assess skills gaps. Consult on legislation. Encouraged to adopt sustainable waste management practises and drive change through procurement.
Regional	Provide waste collection services and implement engagement campaigns. Support alternatives to landfill and encourage systems that treat waste as a resource to ensure greater consistency in recycled materials. Collect and report data to evaluate progress towards waste prevention goals, best practice, and value for money.
Waste Sector	Adhere to legislation. Implement waste strategy. Provide waste collection services. Introduce programmes/initiatives that promote closed loop recycling. Assess infrastructure requirements. Establish integrated networks of waste facilities. Address skills gaps and increase the number of green jobs.
Other Business & Industry	Implement waste strategy. Adhere to sector specific plans (and achieve sector-specific targets). Develop and implement voluntary arrangements that consider the polluter pays principle, extended producer responsibility and IPP. Exert influence through procurement activity. Employ eco-design to reduce product impacts (including use of recycled/alternative materials and avoiding the generation of legacy wastes). Contribute to feedback mechanism by recording and submitting data. Assessing skills gaps within their own sector. Share responsibility for waste generated and future proof against future resource competition.
Consumers	Encouraged to develop local exchange schemes and participate in national educational and engagement schemes. Workers are encouraged to recognise and rethink their influence within the workplace and at home regarding procurement and consumption. Contribute to the well-being of Wales, resource efficiency and waste reduction.

TABLE 6: Stakeholder responsibilities within the Northern Ireland Delivering Resource Efficiency plan.

Stakeholder	Responsibilities
International	Set overarching legislation and objectives. Introduce broad programmes to assist with meeting objectives. Provide access to officials to support implementation of programmes and objectives. Identify financial and non-financial opportunities.
National	Ensure compliance with international policy. Develop (all-island) compatible and complementary policy. Participate in international and UK initiatives. Propose sector-specific targets. Develop domestic re-use and voluntary quality assurance schemes. Reduce burdens on business and support resource efficiency. Collect and publish information on waste flows, commodity prices, and legislative proposals.
Government Departments & Non-Gov. Public Bodies	Develop, monitor and enforce waste management strategy and accompanying policies and regulations. Use a suite of penalties and sanctions to ensure compliance. Grant funds for schemes and initiatives. Develop programmes and educational campaigns. Explore and exploit economies of scales. Support market development. Promote collaboration. Provide information. Instrumental in consulting on strategies, legislation and spatial aspects.
Regional	Adhere to national and international legislation. Use powers to improve the quality of the environment. Responsible for planning aspects of waste management strategies. Work in partnership with regulators, other regional stakeholders and the third sector to tackle poor compliance, develop schemes and initiatives, and provide advice. Collect and report data. Provide evidence to consultations and participate in studies, campaigns and inspections.
Waste Sector	Adhere to national and international legislation and permit/ licence conditions. Deliver domestic targets and actions. Develop and utilise programmes and investment schemes to introduce innovative waste collection schemes and integrate facilities on an all-island basis. Implement codes of practice. Support local authorities and communities to adhere to the waste hierarchy. Contribute to consultations. Collect and report data regarding specific waste streams.
Other Business & Industry	Adhere to national and international legislation, and sector specific domestic targets. Develop and participate in voluntary initiatives. Build market confidence. Consider best available techniques.
Consumers	Participate in campaigns. Promote social enterprise along with green jobs. Instigate improvement through public engagement and social acceptance.

improve environmental performance, where this consideration did not feature in the other strategies.

4.3 Implementation of EU policy and future implications

Analysis of these four documents illustrates point made by Garcia Quesada (2014) that the amount of discretion given to member states to implement EU objectives can lead to significant differences (and success) in national implementation. Where England has transposed EU policy with "no gold-plating" (minimum requirements), Wales in particular can be argued to have had more success in using the "gold-plating" (going beyond minimum requirements) approach (Anker et al.,, 2015). Indeed, it is noted that the English document incorporates and combines existing policy into one document without introducing new approaches. This is fundamentally different to Scotland, Wales and NI who all aim to set a strategic direction. Having said that, while NI does set a strategic direction, like England, its emphasis remains on meeting the requirements set out by the EU. In comparison, Scotland and Wales appear much more proactive, extending their strategies beyond EU requirements, influencing policy not in their direct control to achieve their individual goals, and understanding the need for, and instigating, change. This observation agrees with Winans et al (2017) and Scotford and Robinson (2013), regarding the superiority of Welsh and Scottish environmental policy within the UK, in that the strategies they promote are more progressive, but like England and NI they continue to refer to overarching objectives set by the EU.

Differences in approach may have contributed to differing levels of success with respect to EU targets. This disagrees with Andrews and Martin (2010) who found no variation in waste management services between the four devolved administrations, attributing this to objectives being set at a supranational level (i.e. by the EU). Conversely, these findings agree with Falmer et al (2013) who noted marked differences in the management strategies employed by the four devolved nations, connecting this to a lack of clarity and direction within overarching waste policy. This analysis found that in the period since strategy publication (2010 for Scotland and Wales; 2013 for England and NI), both Scotland and Wales have implemented strategy that has reduced waste generation, increased recycling rates and reduced landfilling of BMW, with Wales achieving a landfill rate reduction of over 50%. In comparison, waste generation in England and NI has increased and varying results are reported for recycling and landfilling. In England, while the landfill rate has been reduced, the rate of recycling has plateaued, remaining at 44.2%. Whereas in NI, both recycling and landfill rates have increased. With respect to EU targets, all four nations have achieved the landfill directive of no more than 55% BWM landfilled by 2016, and Wales has already surpassed the recycling rate target set by WFD of at least 50% by 2020. While it could be suggested that Scotland and NI are progressing towards meeting this target, the plateauing of England recycling rate could suggest its current strategy may struggle.

Overall, limitations for all of the strategies are a continued focus on waste management rather than resource utilisation, and the reliance on EU targets and objectives to set national priorities. This issue may become more pertinent after Brexit due to an absence of overarching UK strategy, which would have previously been supplied by the EU. While it appears that Wales and Scotland do have long-term policy objectives (including to future proof and avoid 'lock in') and have started the process of incorporating waste management strategy into the broader context of resource management and sustainable development, this is generally absent from the English (and therefore overall UK) strategy. This lack of coherence in objectives and enforcement across the four devolved nations may lead to further complications in the future. As suggested by Scotford and Robinson (2013), diverging amendments enacted by devolved administrations may lead to increased fragmentation and disparity of UK environmental policy.

5. CONCLUSIONS

An alternative to the linear economy model, the CE has been advocated internationally as a solution to current unsustainable consumption patterns. It aims to reduce consumption, recirculate products and materials, and prevent environmental degradation. In response, the EU has developed the forthcoming CEP to provide more stringent objectives and targets, reiterate the waste hierarchy, promote industrial symbiosis and elevate the role of resource efficiency. As with previous EU strategies, member states will be required to transpose the CEP into national strategy and achieve its targets and objectives. While the CEP does provide the correct direction for member states to initiate a transition toward the CE, it has also been criticised for its continued focus on waste management with too little emphasis on high priority waste hierarchy categories such as reduce and reuse.

This study developed a framework based on CE-related literature in which an overall CE definition was identified, along with the importance of R-imperatives (in particular the waste hierarchy) and stakeholder engagement. The framework was used to assess the current waste strategies of the four devolved UK nations (England, Scotland, Wales and NI). Differences in interpretation and implementation of current EU objectives were identified across the devolved nations, with Wales and Scotland promoting more progressive strategies and showing greater improvement regarding EU waste targets. This confirms the conclusion of previous studies that Wales and Scotland currently have the most progressive waste management strategy of the four devolved nations.

The future of waste management strategy in the UK, will be shaped by the CEP and potential ramifications of Brexit. In the short to medium term, adoption of the CEP will provide overarching objectives and targets for the UK due to transposition into national policy. Long term objectives will depend on changes implemented by the UK government. In addition, enforcement that has previously been supplied by the EU to ensure objectives and targets are met may not be present unless a UK wide enforcement system is adopted. This may become an area of contention if Scotland and Wales, who already promote progressive waste strategies, were to diverge further. To address this issue, it is imperative that strong cross-party support is gained for long-term CE objectives both within each devolved parliament and across the UK. This would prevent the return of waste strategy politicisation that was successfully overcome on joining the EU due to the primacy of European law.

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Appendix 3: Fletcher et al., 2018

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Full length article

Unintended consequences of secondary legislation: A case study of the UK landfill tax (qualifying fines) order 2015

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ABSTRACT

Increasing attention is being paid to the use of policy instruments in promoting progressive waste management and supporting the transition to a circular economy. To be effective in this context, instruments must be balanced, providing the correct amount of sanction and incentive to ensure environmental protection, enhance resource recovery, and promote innovation and investment in beneficial technologies. Focusing on the UK landfill tax, and adopting a stakeholder-oriented approach, this paper presents a case study illustrating how the ineffective implementation of secondary legislation can have unintended consequences on the aims of primary legislation. Specifically, it examines the Landfill Tax (Qualifying Fines) Order 2015 (QFO), which introduced a Loss On Ignition (LOI) test regime to classify fines for tax purposes. Results from a stakeholder survey (n = 44) revealed that the introduction of the QFO has dis-incentivised material recovery and discouraged investment in separation technologies, thereby creating a perverse incentive to landfill waste. Major weaknesses identified include the poorly defined LOI test regime, the timing of and responsibility for conducting LOI testing, the lack of compliance checks, and the marked discontinuity in tax rates at the somewhat arbitrary 10% LOI threshold. Furthermore, the system was widely viewed to be open to abuse by unscrupulous traders. A set of recommendations are made to address these shortcomings, where it is proposed that the LOI threshold should be replaced by multiple tax bands or a sliding scale and ideally combined with a direct incentive for investment such as an enhanced capital allowance for resource efficient technologies.

1. Introduction

Transitioning from a linear to a Circular Economy (CE) could overcome consequences of unsustainable consumption such as environmental degradation, resource depletion, and climate change (Moreno et al., 2016). A CE mimics a natural biological system by recirculating resources through successive generations, where resource efficiency is promoted through the optimisation of production systems, resource utility is maintained by extracting the maximum value when in use, and any remaining value at end-of-life is recovered through progressive waste management strategies (Smol et al., 2015).

There is now growing attention on the role of policy in delivering the CE. Soderman et al. (2016) notes that the European Union (EU) is increasingly recognising the role of policy in supporting the transition from end-of-pipe waste management to efficient resource management, whilst Jimenez-Rivero and Garcia-Navarro (2017) highlight the need for government to strengthen and enforce instruments that adhere to CE principles. One CE-aligned approach is the use of Extended Producer Responsibility (EPR), which places responsibility for end-of-life management with the producer (Lindhqvist, 2000). Currently the use of EPR (in the EU and elsewhere, e.g. Mrkajić et al., 2018; Wang et al., 2018) is restricted at a practical level to packaging waste, waste electrical and electronic equipment, end-of-life vehicles, and hazardous household wastes (Lifset et al., 2013). For an ideal CE approach, this would extend to up-stream issues such as eco-design, along with full internalisation of waste management costs to shift responsibility from taxpayers and local authorities to companies and consumers (Lifset et al., 2013). While this may be realised in the future, during the transition end-of-pipe waste management remains a key concern. Indeed, EU policy initiatives, the most recent being the 'Circular Economy Package (CEP)' (2015-ongoing; European Commission EC, 2016), place an increased emphasis on both CE models and the efficient use of wastes (Gregson et al., 2015; Smol et al., 2015).

With respect to waste management, two key EU directives are the Waste Framework Directive (WFD) (2008/98/EC), which introduces the waste hierarchy and sets recycling targets, and the Landfill Directive (LD) (1999/31/EC), which sets targets requiring a reduction in the landfilling of biodegradable and other polluting solid wastes

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(European Commission EC, 2008, 1999). Both the WFD and the LD have been amended by the CEP, which reiterates the waste hierarchy, strengthens recycling targets, and extends landfill diversion targets to include all municipal wastes (European Commission EC, 2015a,b).

Although all member states are obliged to transpose EU directives into national policy, economic and social differences between countries are reflected in the disparity of waste management systems employed (Mihai and Apostol, 2012; Pires et al., 2011). Concerning landfill diversion, several countries have achieved very low landfilling rates, where this has been attributed to effective national policy and the use of fiscal measures such as Landfill Taxes (LFTs) (European Environment Agency EEA, 2000; Mazzanti et al., 2009).

While LFTs have been successful in diverting waste from landfill, to what extent they promote material recovery is less clear. The financial competitiveness of secondary materials can be enhanced through taxation on competing virgin materials or on waste disposal, where Solderholm (2011) argues that the latter can be more effective due to low administration costs and increased policy acceptance. However, Martin and Scott (2003) found that while the United Kingdom (UK) LFT had increased landfill diversion, it had been less successful in promoting the top waste hierarchy priorities. Likewise, in an EU-wide study, Mazzanti and Zoboli (2008) concluded that while LFTs can lead to the management of waste being promoted up the waste hierarchy (to recovery or recycling), they do not create a backwards incentive to reduce waste generation. To address such issues, researchers have called for a re-framing of the waste hierarchy in terms of resource use and productivity, arguing that this would help policy makers ensure that they not only disincentivise disposal, but also adequately incentivise preferred environmental options (Gharfalkar et al., 2015; Van Ewijk and Stegemann, 2014).

Another factor that requires consideration is the evolution of policy instruments in response to technological advancements in waste processing, with particular attention paid to the interaction between the negative externalities of pollution and the positive externalities of technological innovation (Leme et al., 2014; Luz et al., 2015). Jaffe et al. (2003) argue that policies targeting pollution reduction should also support technological change. Thus, there is a case for combining environmental taxes with direct incentives if the signal from a single instrument is insufficient to promote innovation and adoption of beneficial technologies (Jaffe et al., 2005). Likewise, Bennear and Stavins (2007) argue that in such "second-best" settings, which are common in the area of environmental and resource management, the use of multiple instruments is both the norm and justifiable. However, they also caution that this requires a high level of policy coordination, which may extend to an instrument designed to address one issue being modified in light of another to achieve an overall positive outcome (Bennear and Stavins, 2007).

While the design of appropriate policy instruments is clearly important, it is equally important to ensure the desired impact is achieved through effective implementation (Soderman et al., 2016). In this context, Bailey and Rupp (2005) contend that implementation cannot be fully understood or improved without due consideration of stakeholder perspectives, arguing that industry is uniquely placed to make a valuable contribution towards understanding the strengths and weaknesses of environmental policy instruments. Indeed, numerous stakeholder-related factors have been identified that could undermine implementation, including a lack of competent staff, ineffective administrative capabilities, incoherent or uncomprehensive written documentation, poor inter-organisational communication and support, a lack of cooperation, and competing priorities (Bailey and Rupp, 2005; Khan and Khandaker, 2016; Mosannenzadeh et al., 2017; McTigue et al., 2018). In relation to the latter point, Bailey and Rupp (2005) found that eco-taxes may be counter-productive if a reduction in profitability leads to the de-prioritisation of environmental issues. This again highlights the need to find a balance between competing priorities (or multiple market failures) in waste management policy in order to encourage development of optimal systems. Otherwise, under-regulation may lead to the careless handling of wastes, while over-regulation, regulation that is unclear, or an absence of compensatory incentives, may hinder the re-use of waste materials by creating excessive bureaucracy and stifling innovation (Gharfalkar et al., 2015; Jaffe et al., 2005).

This paper presents a case study illustrating how the ineffective implementation of secondary legislation can have unintended consequences on achieving the aims of primary legislation. Focusing on the UK LFT, it employs a stakeholder survey to examine how the introduction of the Landfill Tax (Qualifying Fines) Order 2015 (QFO) (House of Commons HoC, 2015), a statutory instrument used to classify waste, has impacted on stakeholders. Expanding on a preliminary analysis (Fletcher et al., 2017) it examines how the QFO may disincentivise material recovery and thereby limit landfill diversion, where consideration is given to potential modifications that would ensure sufficient environmental protection while enhancing the economic viability of waste processing. The paper is structured as follows. Section 2 outlines the development of the UK LFT and QFO. Section 3 details the methods used to conduct the analysis. Section 4 discusses stakeholder views on the design and implementation of the QFO, highlighting barriers to material recovery and landfill diversion, and suggesting potential policy developments. Finally, Section 5 reviews the wider implications and conclusions of the study.

2. The UK landfill tax

The UK LFT facilitates the implementation of the LD (Calaf-Forn et al., 2014; Morris et al., 2000), and was introduced in the 1996 Finance Act (HM Stationary Office HMSO, 1996) and modified in the Landfill Tax (Amendment) Regulation 2009 (HM Stationary Office HMSO, 2009). A regulatory incentive administrated by Her Majesty's Revenue and Customs (HMRC), the LFT applies differential tax rates to wastes disposed of to landfill in order to reflect the environmental burden of this disposal option (Calaf-Forn et al., 2014; Grigg and Read, 2001; Morris et al., 2000). It defines inert (or inactive) waste, which qualifies for a lower tax rate, as non-hazardous (as described by the WFD), with a low Greenhouse Gas (GHG) emission potential (not biodegradable) and low polluting potential (contaminants unlikely to become mobile or leach). Any waste that does not conform to these criteria is classed as active and is liable for the standard tax rate (HMRC, 2016a). In accordance with Section 42(2) of the Finance Act 1996(a), a definitive list of materials that were deemed to meet the definition of inert waste (for the purposes of setting the LFT rate, and based on well characterised properties) was published. Originally delivered through the Landfill Tax (Qualifying Materials) Order 1996 (QMO) and updated in 2011, the materials listed include; naturally occurring materials (rocks, sand and soils), low activity processed materials (glass, ceramics or concrete), processed or prepared minerals (silica, mica or clay), furnace slags, ash, low activity inorganic compounds, calcium sulphate, and calcium hydroxide (including brine) (House of Commons HoC, 2011, 1996).

When first introduced, the LFT rates were £2/tonne for inert waste and £7/tonne for active waste, thus with gate fees of around £5–£15 (ENDS, 1994) total disposal costs remained relatively low. As such, the LFT provided little financial incentive for diversion and had minimal effect on the amount of waste being disposed to landfill (Martin and Scott, 2003). To address this legislative failure, the LFT escalator was introduced (HM Treasury, 1999; Martin and Scott, 2003), where the price of landfilling active waste increased by a fixed amount each year from 2000 to 2014. Since 2015, both the active and inert tax rates have been index linked (HMRC, 2016b), standing at £84.40/tonne for active waste and £2.65/tonne for inert waste in 2016/17 (HMRC, 2016a). Although gate fees have also increased (partly reflecting improved landfill management practices) they have been relatively stable since 2008, with a mean of £22/tonne in 2016 (The Waste and Resources

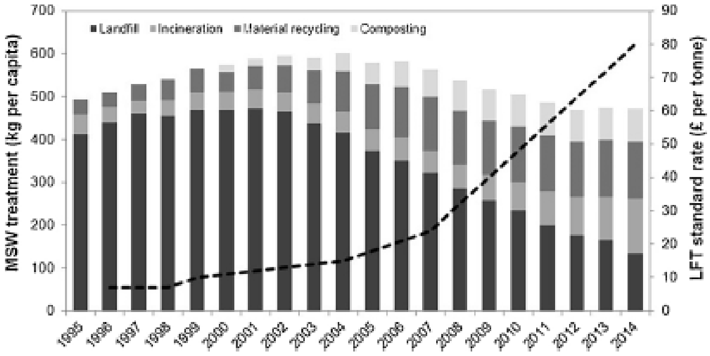

Fig. 1. Impact of the UK landfill tax on the management of Municipal Solid Waste. The landfill tax liability for standard-rated materials is from HMRC (2016a). Waste management data are from Eurostat (2016).

Action Programme WRAP, 2009, 2017). Thus, for active waste the tax liability now clearly exceeds other disposal costs, and the total disposal cost (around £106/tonne) is considerably higher than that for inert waste (around £25/tonne).

The LFT is applied to all non-exempt wastes, with the standard rate typically applied to Municipal Solid Waste (MSW) and hazardous waste, and the lower rate typically applied to Construction and Demolition (C &D) waste (Conran, 2017). While sufficient data is not available to assess the impact of the LFT on all waste streams, it is available for MSW (Fig. 1), where it can be seen that the LFT escalator incentivised a dramatic reduction in landfilling of around 50% between 2000 and 2013, with a concomitant fivefold increase in other waste treatment methods (Eurostat, 2016; HMRC, 2016a). Indeed, in the management of MSW the removal of recyclable materials, such as glass, high-grade plastics and metals, is now routine (Beccali et al., 2001; Santibanez-Aguilar et al., 2013). Likewise, combustibles (e.g. low-grade plastics and textiles) are often separated and used as refuse derived fuel (Násner et al., 2017; Vountatsos et al., 2016), while biodegradable materials (e.g. food and garden wastes) are often removed and composted or used in energy generation (Santibanez-Aguilar et al., 2013). This has been achieved through source segregation and more recently through technological separation at mechanical biological treatment and material recovery facilities (Cook et al., 2015; Vountatsos et al., 2016), where such approaches are also employed in the management of C&D and other wastes. While advanced processing methods have delivered gains in material and energy recovery, they have not delivered (and cannot deliver) full recovery, where landfill disposal remains the preferred option for residual waste streams (Beccali et al., 2001; Santibanez-Aguilar et al., 2013). Thus, in addition to a reduction in the amount of landfilled waste, another consequence of technological advancement has been a change in the nature of wastes sent to landfill, with an increasing contribution from 'fines' (the small fragments that remain after processing via a mechanical treatment such as trommel screens, HMRC, 2016a). As the composition of fines is highly variable, being dependent on both the composition of the input waste and the separation techniques employed (Dias et al., 2012), this change in the nature of landfilled waste has given rise to a key question regarding the classification of fines as either active or inactive.

As fines are often processed from a mixed waste (and therefore contain a mixture of materials), even those arising from waste streams dominated by inert materials (e.g. C&D waste) may not consist of qualifying materials (listed as inert in the QMO) in their entirety (Balch, 2014). While the QMO does make allowance for the presence of a 'small' amount of active waste, known as 'incidentals', what constitutes a small amount is not clearly defined. Indeed, only generic guidance is provided, that "whether an amount of standard-rated waste [i.e. active waste that is liable for the standard tax rate] is small will depend on the circumstances and is a matter of fact and degree. As a guide, the dictionary definition of small is either small in size or weight, or insignificant or unimportant" (HMRC, 2016a). Thus, in the absence of a clear definition, what emerged in practice was a relatively informal system, where the responsibility of determining whether an amount of incidental material qualified as small rested with the landfill operator (HMRC, 2016a). As such, the classification of fines has been strongly debated within the waste industry, with concerns that the lower rate of tax was not being applied equitably and that more clarity was required concerning liability (Balch, 2014; Goulding, 2015a,b).

To address these concerns, the waste industry was consulted on proposed secondary legislation to use a standardised Loss On Ignition (LOI) test to classify fines where an LOI of 10% or less would indicate inert material with a 'small' amount of contamination (HMRC, 2014a). Overall, respondents agreed with the proposal, but raised concerns regarding conformity of fines to the QMO, time required for businesses to adjust, the 10% LOI limit, and operational aspects of the LOI test (HMRC, 2014b). A number of revisions were made in response, including a prescribed LOI testing regime, and the QFO was introduced where responsibility and liability for implementation was placed primarily with the landfill operator, but where correct classification of fines was also dependent on information provided by the waste processor (Fig. 2).

While the QFO provided a degree of clarity on the classification of fines, debate continued regarding the economic and practical realities of implementation (Balch, 2014; Coll, 2015). The QFO has seen some materials that may have qualified as inert (based on the QMO and the interpretation of a 'small' amount of incidentals) now classed as active waste unless proven otherwise, creating uncertainty and scepticism amongst operators (Balch, 2014; Coll, 2015). Furthermore, while the QFO has encouraged further material recovery in some cases (e.g. removal of metal fragments from C&D derived fines to reduce the total weight of fines sent to landfill), it has been suggested that in other cases it may reduce the financial viability of recycling operations, thereby acting contrary to the intended incentive (Coll, 2015).

These issues are further compounded by concerns regarding the reliability of the LOI test regime (Goulding, 2016, 2015a,b). While the prescribed sampling method attempts to homogenise loads, Goulding (2015a,b) has provided anecdotal evidence that it can be manipulated. Similarly, Goulding (2016, 2015a) cites concerns raised by test providers regarding differing interpretation of the LOI test method and the consistency of data produced.

3. Materials and methods

Considering the ongoing areas of debate regarding the QFO, a survey of waste management stakeholders was conducted to solicit

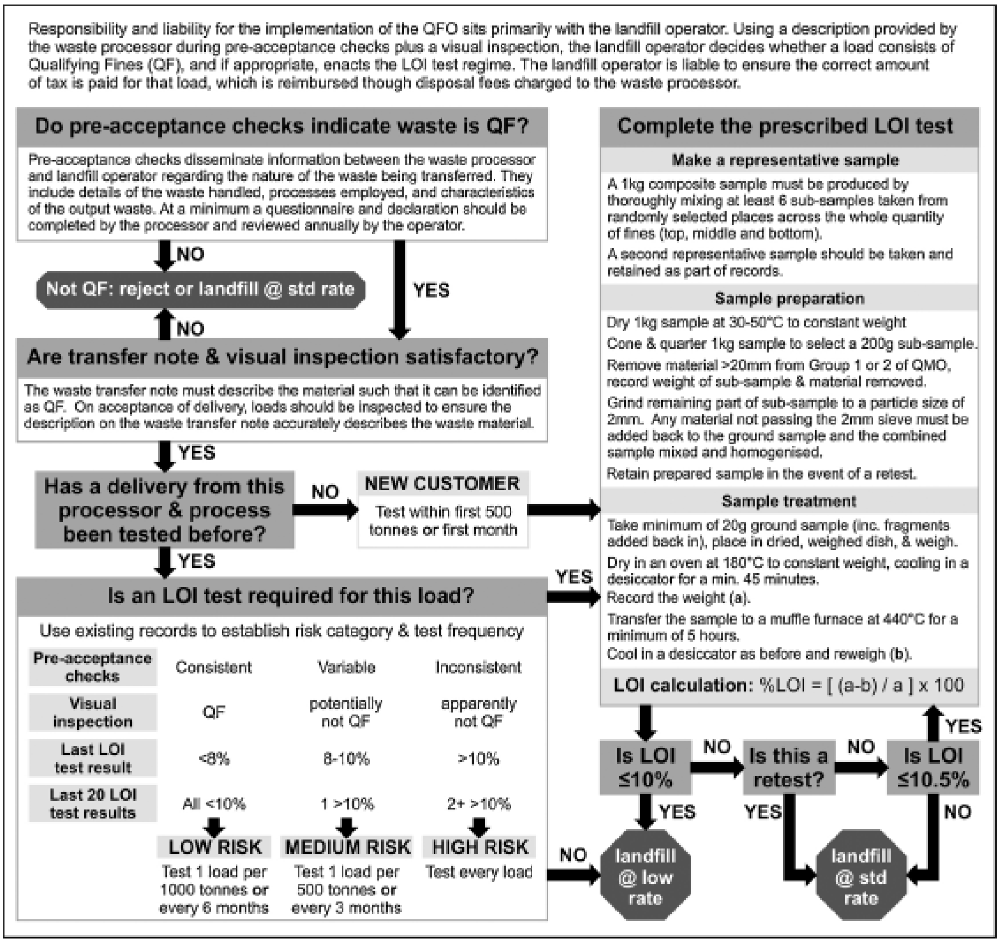

Fig. 2. The process for determining the appropriate landfill tax rate for residual fines in accordance with the Landfill Tax (Qualifying Fines) Order 2015. Based on the guidance provided by HMRC (2016a).

views on the implementation of the QFO with a focus on the LOI testing regime. Specifically, the survey sought to ascertain opinions regarding previously identified issues and potential proposed solutions in order to inform recommendations for policy development.

The survey instrument was an online self-administered questionnaire created and published using SurveyMonkey (see Appendix A1 in Supplementary material for a full copy). Questionnaire development was informed by industry literature (Balch, 2014; Coll, 2015; Goulding, 2016, 2015a,b) and discussions on fines management at an open meeting hosted by the Chartered Institute for Waste Managers (CIWM) on 4th March 2016 at the Cotton Exchange, Liverpool, UK. Key issues identified included impacts on workplace resource requirements (Balch, 2014; Coll, 2015), a lack of support for implementation, and poor reliability of the testing regime (Goulding, 2016; 2015a,b). These points were reiterated at the CIWM meeting, where a number of potential modifications were also proposed, including the introduction of additional tax bands or spike allowances, laboratory accreditation, and third-party sampling.

A qualifying question was employed to ensure only stakeholders whose work related to or was impacted by the LOI testing regime proceeded. To enable categorisation of responses by stakeholder groups, qualifying respondents were first asked questions regarding their sector and the nature of their connection to the production, management, or testing of fines. This was followed by questions addressing the perceived impact of the LOI testing regime on workplace resource requirements, opinions regarding issues identified with the LOI testing regime, and opinions regarding the proposed potential modifications.

The questionnaire employed closed questions with optional open comment boxes to instigate elaboration. Opinions were measured using Likert-type rating scales (Likert, 1932), where the response format was selected to minimise the risk of introducing bias and followed the recommendation of Revilla et al. (2014) to employ a five point fully labelled scale with a neutral midpoint for opinion measurement in the general population. To ensure respondents were not forced to specify an opinion, thereby introducing a response bias (Friedman and Amoo, 1999), 'don't know' and 'not applicable' (N/A) options were also included. While such responses are commonly excluded from analysis, doing so without consideration of potential consequences can lead to biased results and lost information (Kroh, 2006; Wang, 1997). Here all 'don't know' and the majority of 'N/A' responses were considered to reflect either a genuine lack of knowledge on the subject and/or cases where the topic did not apply to the respondent, and were excluded. However, 'N/A' responses regarding the impact of the LOI testing regime on resource requirements were retained and treated as equivalent to a neutral response.

An invitation to participate was sent to 311 individual email addresses, comprising 27 CIWM meeting delegates and 294 addresses identified from web searches for waste management organisations (within a 15-mile radius of 24 UK urbanisations), commercial laboratories offering LOI testing, and waste research groups. The questionnaire link, with accompanying invitation, was also featured in the CIWM newsletter, Skip Hire magazine, and member communications of the United Resource Operatives Consortium. The invitation informed respondents about the purpose of the study, anonymity of responses, and intended publication of results with key recommendations. To enhance response rates an incentive was offered, whereby respondents could opt in to a prize draw. In total 44 complete responses were received in the period 9th June to 1st August 2016. This is consistent with similar surveys within waste management, which have received 12–35 responses (Eskandari et al., 2012; Glew et al., 2013).

Quantitative data from the closed questions were analysed using Microsoft Excel 2013 and SPSS (v.22) to produce frequency distributions and to test for differences between stakeholder groups. There is marked variation in practice and debate in the literature regarding the appropriate statistical analysis of Likert-type data (Bishop and Herron, 2015; Carifio and Perla, 2008; Jamieson, 2004). As this study is exploratory in nature, with analysis carried out at the level of individual questions, a conservative approach was adopted and the data was treated as ordinal, with the nonparametric Pearson's Chi-Square (X^2) statistic used to test for differences between groups (Jamieson, 2004; McHugh, 2012). Unless otherwise stated, differences between groups were insignificant. Qualitative data (comments from open comment boxes) were used to enrich the quantitative responses and to identify areas of agreement and conflict.

4. Results and discussion

4.1. Respondent profile

Table 1 presents a breakdown of respondents categorised by organisation type and connection to the LOI testing regime. Of the 30 respondents who provided their job title, all held managerial or professional positions (Office of National Statistics, ONS, 2010). Overall, the respondent profile demonstrates that expert opinion from within the waste industry and associated sectors contributed to the survey, indicating good representation for the results.

4.2. Workplace resource requirements

Two-thirds of respondents reported some increase in resource requirements when the LOI testing regime was introduced, where the most frequently cited were an increased time requirement and paperwork burden. Group 1 were significantly more impacted than group 2, reflecting their direct engagement in the management of fines (Table 2).

Around two-fifths of respondents reported an increase in financial resource requirements, including capital expenditure and/or

Table 1
Respondent profile categorised according to their connection to the management of fines.

Group 1: Direct connection (n = 27) *Production and disposal of fines*	Group 2: Indirect connection (n = 17) *Policy development & regulation, auxiliary services, research.*
Waste processing (16) Landfill operation (5) Internal policy compliance (6)	Policy development & regulation (4) Waste consultancy (4) Test provider (6) Waste machinery supplier (1) Academic research (2)

Table 2
Respondent opinion regarding the impact of the LOI testing regime on workplace resource requirements. Significant differences in responses between groups are highlighted.

	All Respondents					Group 1: Direct Connection					Group 2: Indirect Connection					Chi-squared test Group 1 v Group 2		
Workplace Aspect	Large increase # (%)	Small increase # (%)	Neutral # (%)	Small decrease # (%)	Large decrease # (%)	Large increase # (%)	Small increase # (%)	Neutral # (%)	Small decrease # (%)	Large decrease # (%)	Large increase # (%)	Small increase # (%)	Neutral # (%)	Small decrease # (%)	Large decrease # (%)	X^2	df	P-value
Time allocation	6 *(14%)*	23 *(52%)*	15 *(34%)*	0 *(0%)*	0 *(0%)*	5 *(19%)*	18 *(67%)*	4 *(15%)*	0 *(0%)*	0 *(0%)*	1 *(6%)*	5 *(29%)*	11 *(65%)*	0 *(0%)*	0 *(0%)*	11.6	2	**0.003**
Paperwork	5 *(11%)*	20 *(45%)*	19 *(43%)*	0 *(0%)*	0 *(0%)*	5 *(19%)*	18 *(67%)*	4 *(15%)*	0 *(0%)*	0 *(0%)*	0 *(0%)*	2 *(12%)*	15 *(88%)*	0 *(0%)*	0 *(0%)*	23.1	2	**0.000**
Capital expenditure	7 *(17%)*	9 *(21%)*	26 *(62%)*	0 *(0%)*	0 *(0%)*	6 *(24%)*	8 *(32%)*	11 *(44%)*	0 *(0%)*	0 *(0%)*	1 *(6%)*	1 *(6%)*	15 *(88%)*	0 *(0%)*	0 *(0%)*	7.26	2	0.270
Operational costs	8 *(20%)*	6 *(15%)*	27 *(66%)*	0 *(0%)*	0 *(0%)*	6 *(25%)*	6 *(25%)*	12 *(50%)*	0 *(0%)*	0 *(0%)*	2 *(12%)*	0 *(0%)*	15 *(88%)*	0 *(0%)*	0 *(0%)*	7.35	2	**0.025**
Staff numbers	1 *(2%)*	5 *(12%)*	37 *(86%)*	0 *(0%)*	0 *(0%)*	1 *(4%)*	4 *(15%)*	21 *(18%)*	0 *(0%)*	0 *(0%)*	0 *(0%)*	1 *(6%)*	16 *(94%)*	0 *(0%)*	0 *(0%)*	1.67	2	0.435
Maximum impact for any aspect	11 *(30%)*	18 *(49%)*	8 *(22%)*	0 *(0%)*	0 *(0%)*	9 *(36%)*	14 *(56%)*	2 *(8%)*	0 *(0%)*	0 *(0%)*	2 *(17%)*	4 *(33%)*	6 *(50%)*	0 *(0%)*	0 *(0%)*	8.49	2	**0.014**

operational costs. One respondent who identified a neutral impact on capital expenditure noted that it might be required in the future, but "until the problems relating to variability and accuracy of testing can be overcome, the type and level of expenditure cannot be determined."

While, six respondents reported an increase in staff requirements, one respondent highlighted a potential negative impact on future employment. Here, the 'huge' increase in operational expenditure was leading a private waste management company to evaluate the financial viability of their sorting stations, where the absence of tax savings in combination with the low value of separated materials results could lead to the plants becoming redundant.

4.3. The 10% LOI threshold

The current 10% LOI limit sets the threshold between the low and standard tax rates. When asked whether they thought the 10% LOI limit appropriately represented the characteristics of an inert waste, less than half (14) of the respondents (n = 33) agreed. Five respondents (all from group 1) thought it was too low, citing concerns related to the definition of qualifying fines. Eight respondents (from both groups) thought it was too high, noting that fines with 10% LOI "can still generate significant amounts of GHG". Of the six respondents who cited other reasons, half highlighted that it focused solely on GHG emissions taking no account of other factors that influence toxicity or odour potential. Others noted that it appeared to penalise recycling and recovery, where the marked step in tax liabilities at the threshold was viewed as punitive and failing to reflect the efforts made by operators to improve waste treatment.

4.3.1. Proposed modifications to the 10% LOI threshold

Respondents' views on four potential modifications to the 10% LOI threshold are presented in Table 3A.

Proposals to either increase or decrease the current threshold were not widely supported, with around four-fifths of respondents giving a neutral or negative response. Not unexpectedly, support for these proposals mirrored views on the appropriateness of the threshold, with those who considered it to be too low or too high favouring an increase or decrease respectively.

Proposals to replace the sharp threshold with banding (where one or more additional tax brackets are introduced for fines with intermediate LOI) received a mixed response. Around half of the respondents supported the addition of one extra band, with around a third opposed, and a sixth neutral. Overall support for multiple bands was somewhat lower, with a broadly even split between supportive, opposing, and neutral responses. However, there were significant differences between the groups, where group 1 supported multiple bands and group 2 opposed.

Group 1 viewed banding as a means of removing the perceived disincentives to material recovery arguing that banding would strengthen the economic viability of processing operations, and with one respondent suggesting a sliding tax scale (with an increase in tax rate on the order of £5 for each percentage point above the threshold) would be a preferred solution.

For the most part, group 2 did not oppose the principle of banding, but held concerns regarding the ability to implement it. Respondents noted that the LOI test is neither precise nor accurate enough to support banding, and identified specific issues with the methodology (e.g. missing details regarding vessel size, and depth/surface area of the sample) that further contributed to a high variation in test results within and between laboratories. Indeed, a number of respondents highlighted that this variation (reported to be around 2%) leads the current regime (under which significant additional cost is incurred if the LOI test result is 0.1% over the threshold) to be perceived as unfair, and suggested that the tax threshold should reflect this (un)reliability, potentially through inclusion of an allowable measurement error.

4.4. Frequency of fines testing

Test frequency is dependent on previous performance, taking into account consistency of pre-acceptance checks, outcome of visual inspections, and prior LOI results. Respondents were asked to what extent they agreed that; (1) the test regime is very clear and the testing frequency is easy to determine, and (2) the risk categories used to determine testing frequency are fair (Table 3B).

Around a third of respondents considered the method to be unclear and/or unfair. Concerns were related to the practicability of the test regime due to the size of operations and the time delays between delivery of waste to site and receiving test results. Respondents also highlighted that the current regime is open to abuse, indicating that some operators may discard test results to avoid moving into higher risk categories (thereby avoiding higher test frequencies and associated costs).

4.4.1. Proposed modifications to determination of test frequency

Respondents views on four potential modifications to the method for determining test frequency are presented in Table 3C. Only the introduction of a spike allowance received wide support, with less than a third of respondents supporting the other suggestions.

While it was acknowledged that a fixed number of tests would be simpler, respondents also noted that it could lead to an increased overall burden. The risk that a prescribed test schedule would be open to abuse (e.g. through the provision of compliant but atypical samples) was also identified, with one respondent noting "huge savings could be made from bad practice".

Proposals to either increase or decrease the number of risk categories received the least support, where respondents highlighted that the use of risk categories (even those established) was unworkable due to the inherent variability of the materials, length of time required to test a sample, and the poor accuracy and precision of the test.

Around four-fifths of respondents supported the introduction of a spike allowance, with stronger support (and no opposition) from group. One opposing respondent from group 2 noted that the introduction of spike allowances would defeat the object of the LOI testing regime. However, a respondent from group 1 suggested that a constrained spike allowance could be built into risk categories, where they considered it would be reasonable to suggest fines remained in the lower risk category if one in ten samples spiked over 10% by no more than 2% (the reported level of variation in the accuracy of the LOI test).

4.5. Support for implementation of the LOI testing regime

When asked their views regarding current support for implementation of the LOI testing regime, more than half of the respondents reported that the support was inadequate, with less than a fifth finding the support adequate (Table 4A). Dissatisfaction was higher in group 1, with a clear majority reporting inadequate support. These respondents perceived a lack of expertise within HMRC regarding the waste industry and waste related taxes, citing the advocacy of a poorly defined test method. Furthermore, some respondents considered that landfilling of waste was effectively "unpoliced", thereby enabling "cowboy operators" (a term used to refer to dishonest or unscrupulous operators) to falsely describe material in order to send it to landfill as inert. To address this issue, one respondent suggested that the HMRC should take the lead in testing more sites to ensure compliance and consistency.

4.5.1. Proposed modifications to support for implementation

Respondents' views on six potential modifications to enhance the support provided for implementation of the LOI testing regime are presented in Table 4B.

The majority of respondents agreed that further support from HMRC would be of a benefit. However, one respondent stated that the

Table 3
Respondent opinion regarding LOI limit and testing frequency. Significant differences in responses between groups are highlighted.

	All Respondents					Group 1: Direct Connection					Group 2: Indirect Connection					Chi-squared test Group 1 vs Group 2		
	Strongly agree # (%)	Agree # (%)	Neutral # (%)	Disagree # (%)	Strongly disagree # (%)	Strongly agree # (%)	Agree # (%)	Neutral # (%)	Disagree # (%)	Strongly disagree # (%)	Strongly agree # (%)	Agree # (%)	Neutral # (%)	Disagree # (%)	Strongly disagree # (%)	X^2	df	P-value
A. Views on potential modifications to the 10% LOI limit																		
Increase the LOI limit	4 *(11%)*	3 *(8%)*	15 *(42%)*	9 *(25%)*	5 *(14%)*	4 *(27%)*	3 *(20%)*	5 *(33%)*	3 *(20%)*	0 *(0%)*	0 *(0%)*	0 *(0%)*	10 *(48%)*	6 *(29%)*	5 *(24%)*	5.95	4	0.203
Decrease the LOI limit	4 *(11%)*	3 *(8%)*	13 *(35%)*	9 *(24%)*	8 *(22%)*	2 *(11%)*	1 *(5%)*	2 *(11%)*	7 *(37%)*	7 *(37%)*	2 *(11%)*	2 *(11%)*	11 *(61%)*	2 *(11%)*	1 *(6%)*	9.36	4	0.053
One additional tax band	3 *(8%)*	16 *(43%)*	6 *(16%)*	6 *(16%)*	6 *(16%)*	1 *(6%)*	11 *(61%)*	3 *(17%)*	2 *(11%)*	1 *(6%)*	2 *(11%)*	5 *(26%)*	3 *(16%)*	4 *(21%)*	5 *(26%)*	7.38	4	0.117
Multiple additional tax bands	8 *(22%)*	4 *(11%)*	11 *(30%)*	8 *(22%)*	6 *(16%)*	7 *(39%)*	4 *(22%)*	4 *(22%)*	2 *(11%)*	1 *(6%)*	1 *(5%)*	0 *(0%)*	7 *(37%)*	6 *(32%)*	5 *(26%)*	10.2	4	**0.037**
B. Views on the current method to determine test frequency																		
The test regime is clear	1 *(3%)*	16 *(41%)*	11 *(28%)*	8 *(21%)*	3 *(8%)*	1 *(5%)*	7 *(33%)*	6 *(29%)*	5 *(24%)*	2 *(10%)*	0 *(0%)*	9 *(50%)*	5 *(28%)*	3 *(17%)*	1 *(6%)*	0.98	4	0.912
The test regime is fair	1 *(3%)*	11 *(29%)*	13 *(34%)*	6 *(16%)*	7 *(18%)*	1 *(5%)*	3 *(14%)*	7 *(33%)*	5 *(24%)*	5 *(24%)*	0 *(0%)*	8 *(47%)*	6 *(35%)*	1 *(6%)*	2 *(12%)*	4.53	4	0.34
C. Views on potential modifications to determination of test frequency																		
Include spike allowance	6 *(15%)*	25 *(64%)*	4 *(10%)*	3 *(8%)*	1 *(3%)*	5 *(29%)*	10 *(59%)*	2 *(12%)*	0 *(0%)*	0 *(0%)*	1 *(5%)*	15 *(68%)*	2 *(9%)*	3 *(14%)*	1 *(5%)*	11.8	4	**0.019**
Fixed number of tests	4 *(11%)*	6 *(16%)*	11 *(30%)*	14 *(38%)*	2 *(5%)*	3 *(16%)*	5 *(26%)*	5 *(26%)*	5 *(26%)*	1 *(5%)*	1 *(6%)*	1 *(6%)*	6 *(33%)*	9 *(50%)*	1 *(6%)*	2.01	4	0.734
Increase number of risk categories	1 *(3%)*	6 *(16%)*	12 *(32%)*	15 *(41%)*	3 *(8%)*	1 *(6%)*	4 *(25%)*	6 *(38%)*	5 *(31%)*	0 *(0%)*	0 *(0%)*	2 *(10%)*	6 *(29%)*	10 *(48%)*	3 *(14%)*	2.99	4	0.559
Decrease number of risk categories	0 *(0%)*	3 *(8%)*	15 *(41%)*	15 *(41%)*	4 *(11%)*	0 *(11%)*	2 *(5%)*	6 *(11%)*	7 *(37%)*	1 *(37%)*	0 *(11%)*	1 *(11%)*	9 *(61%)*	8 *(11%)*	3 *(6%)*	1.02	3	0.796

Table 4
Respondent opinion regarding current and future support available for implementing the LOI testing regime. Significant differences in responses between groups are highlighted.

Option	All					Group 1					Group 2					Chi-squared test Group 1 vs Group 2		
	Strongly agree	Agree	Neutral	Disagree	Strongly disagree	Strongly agree	Agree	Neutral	Disagree	Strongly disagree	Strongly agree	Agree	Neutral	Disagree	Strongly disagree			
	# (%)	# (%)	# (%)	# (%)	# (%)	# (%)	# (%)	# (%)	# (%)	# (%)	# (%)	# (%)	# (%)	# (%)	# (%)	X^2	df	P-value
A. Views on level of current support																		
Adequate support	1 *(3%)*	5 *(14%)*	9 *(26%)*	10 *(29%)*	10 *(29%)*	1 *(6%)*	0 *(0%)*	4 *(22%)*	7 *(39%)*	6 *(33%)*	0 *(0%)*	5 *(29%)*	5 *(29%)*	3 *(18%)*	4 *(24%)*	13.45	4	**0.009**
B. Views on potential modifications for enhanced support																		
Laboratory certification	20 *(45%)*	19 *(43%)*	3 *(7%)*	2 *(5%)*	0 *(0%)*	12 *(57%)*	6 *(29%)*	3 *(14%)*	0 *(0%)*	0 *(0%)*	8 *(35%)*	13 *(57%)*	0 *(0%)*	2 *(9%)*	0 *(0%)*	6.54	3	0.088
Provide more support	9 *(22%)*	26 *(63%)*	4 *(10%)*	1 *(2%)*	1 *(2%)*	6 *(32%)*	11 *(58%)*	2 *(11%)*	0 *(0%)*	0 *(0%)*	3 *(14%)*	15 *(68%)*	2 *(9%)*	1 *(5%)*	1 *(5%)*	3.52	4	0.474
Simplify guidance	7 *(18%)*	23 *(59%)*	7 *(18%)*	2 *(5%)*	0 *(0%)*	4 *(22%)*	10 *(56%)*	4 *(22%)*	0 *(0%)*	0 *(0%)*	3 *(14%)*	13 *(62%)*	3 *(14%)*	2 *(10%)*	0 *(0%)*	3.37	3	0.338
Independent sampling	16 *(37%)*	13 *(30%)*	7 *(16%)*	7 *(16%)*	0 *(0%)*	8 *(40%)*	3 *(15%)*	5 *(25%)*	4 *(20%)*	0 *(0%)*	8 *(35%)*	8 *(35%)*	4 *(17%)*	3 *(13%)*	0 *(0%)*	3.04	3	0.385
Tax breaks for investment	9 *(28%)*	12 *(38%)*	4 *(13%)*	6 *(19%)*	1 *(3%)*	8 *(47%)*	4 *(24%)*	1 *(6%)*	4 *(24%)*	0 *(0%)*	1 *(7%)*	8 *(53%)*	3 *(20%)*	2 *(13%)*	1 *(7%)*	7.94	4	0.094
Process endorsement	6 *(17%)*	9 *(26%)*	3 *(9%)*	9 *(26%)*	8 *(23%)*	5 *(26%)*	7 *(37%)*	2 *(11%)*	4 *(21%)*	1 *(5%)*	1 *(6%)*	2 *(13%)*	1 *(6%)*	5 *(31%)*	7 *(44%)*	8.86	4	0.065

guidance was clear and that it was the responsibility of the operator to understand and comply with all relevant legislation. While this statement of responsibility is indeed correct, it overlooks the key concern raised by multiple respondents that HMRC was not able to provide assistance when asked for clarification regarding the interpretation of the QFO.

The majority of respondents agreed that simplified guidance and a simplified process would be helpful. For example, respondents suggested that the LOI testing regime could be absorbed into the pre-acceptance checks, thus making these checks less subjective, and alleviating the perceived unfair responsibility placed on landfill operators to determine the correct tax rate. While pre-acceptance checks, transfer notes and visual inspections are all used to determine tax rate, as one respondent commented, the landfill operator is heavily reliant on the information provided by the producer, and is therefore reliant on the producer "being both truthful and being able to ensure operatives comply with operating procedures each and every day."

Two thirds of respondents supported the introduction of third party sampling. Respondents who disagreed noted that it would increase costs and timescales. While one respondent insisted that self-sampling was efficient, they also acknowledged that it is open to abuse. Another commented that there is no need for the extra cost burden "as long as the fines are taken to a standardised/accredited Lab and there is the full flow diagram, photo's etc. to support the production process".

LOI test standardisation and laboratory accreditation was the most strongly supported proposal, reflecting the concerns raised throughout the survey regarding the accuracy of the testing regime. Respondents noted this would negate issues concerning margin of error between laboratories and address issues related to the fixing of results. It was also suggested that test providers develop the testing regime so that it addresses concerns relating to accuracy and reliability, where evaluation of the actual margin of error across all (accredited) testing providers could be incorporated into a reframing of the LOI limit (i.e. 10% ± margin of error).

Two thirds of respondents supported the introduction of tax breaks for new technology. While one respondent commented that tax breaks were unnecessary and that technology should be financed through reduced tax liability, earlier responses from group 1 highlighted that uncertainty (in producing fines that qualify for the lower rate of tax) creates barriers to future investment.

Overall, there was a broadly even split between those who supported and opposed process endorsement, where the majority of group 1 were supportive and the majority of group 2 were opposed. One respondent suggested that HMRC should approve processes in combination with third party sampling, with analysts from independent laboratories employed to take random, unannounced samples. However, another respondent (who strongly disagreed) suggested that the focus should be on how inputs influence fines composition. This suggests that the lack of support for process endorsement may at least partly reflect differing interpretations of what that would entail, as a waste separation process is typically designed for a specific input stream. Nonetheless, the point that inputs exert the primary control on the composition of the resultant fines is valid, and if process endorsement were to be pursued, actual inputs must be taken into account.

4.6. *The QFO may act as a barrier to investment*

This research has found that the QFO may act as an unintended barrier to investment in future waste processing, thereby acting contra to the intended goal of the LFT to promote landfill diversion and the more recent policy imperative to enhance material recovery. Due to the low value of separated materials, the financial viability of processing can be poor leading some operators to consider closing existing sorting stations, particularly when anticipated tax savings are not fully realised. Furthermore, uncertainty concerning the accuracy and reliability of the LOI testing regime may negatively impact decisions regarding the type

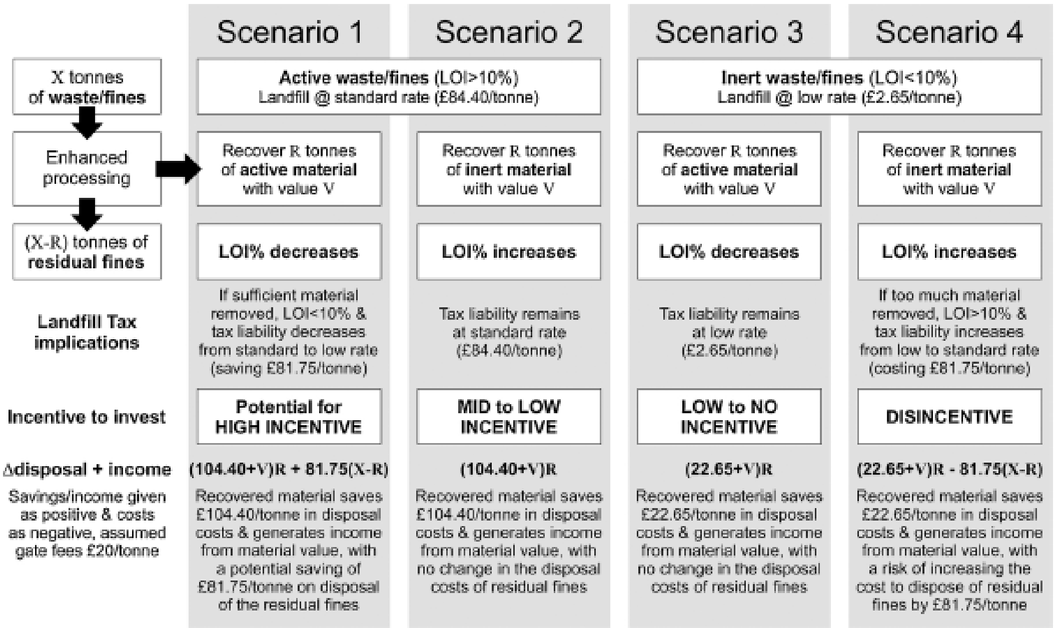

Fig. 3. Level of (dis)incentive to invest in advanced processing of fines taking into account current landfill tax implications of both the input waste and the residual fines.

and level of investment required for advanced processing.

Theoretical scenarios under which the QFO may influence landfill diversion are illustrated in Fig. 3. In scenario one, active wastes have the potential to achieve inert classification after advanced processing to remove active material. This provides the greatest potential incentive for investment due to benefits arising from the significantly decreased disposal costs (reduced tonnage and tax liability of residual fines), in addition to the value of the separated material (expected to be low). However, this incentive depends on the ability to generate a residual fine with 10% LOI or less. In scenario two (removal of inert material from active waste), financial benefits arise only from the reduction in tonnage disposed and the value of the separated material, thus providing a reduced incentive for investment. In scenario three (removal of active material from inert waste), the financial benefits are further reduced due to the original low disposal costs, providing little to no incentive for advanced processing. In scenario four (removal of inert material from inert waste), there is a strong disincentive for further materials recovery due to the risk of residual fines exceeding the 10% LOI limit resulting in significantly increased disposal costs.

These scenarios clearly illustrate the shortcomings of applying a sharp boundary between two disparate tax rates at the somewhat arbitrary 10% LOI threshold. Modifying the tax to one based on multiple bands or a sliding scale has the potential to address this issue, strengthening the incentive for advanced processing in all cases except when the LOI of the original material is marginally greater than 10% and the removal of a small amount of active material would currently trigger a substantial saving. Amalgamating the various proposals put forward by respondents suggests some form of gradation in intermediate tax rates between 5% and 20% LOI would incentivise further separation and alleviate industry concerns that the current tax regime is punitive with a greater focus on revenue generation than environmental protection. This could be strengthened by combining taxation with direct incentives for investment, particularly in cases where the projected return is low or negative, and could potentially be achieved through recycling tax revenue to provide an enhanced capital allowance on 'resource efficient technologies', as is currently available in the UK for a range of energy and water efficient technologies.

4.7. Clarity is needed regarding responsibility for fines classification and LOI testing

A number of issues regarding the implementation of the QFO with respect to the relative responsibilities and liabilities of key stakeholders were raised. This included the perception that the test regime is vulnerable to abuse and concerns over uncertain costs at time of disposal.

At present, the waste processor is required to correctly describe and classify fines, where it is the responsibility of the landfill operator to verify the description, complete an LOI test if necessary, and ensure the correct tax rate is applied. It was suggested that this leaves the landfill operator vulnerable to unscrupulous waste processors (through provision of an incorrect description), and the system vulnerable to unscrupulous landfill operators (if results are manipulated), where there was a perception that the system is virtually unpoliced, with minimal compliance checks taking place.

In addition, due to the time required to complete an LOI test (up to three weeks) a situation may arise where fines are accepted for disposal as inert and are later reclassified as active. This risk of change in tax liability introduces uncertainty into the business models of waste processors and landfill operators, and with respect to the former may create a barrier to investment. Furthermore, a failed test result would require subsequent loads to be tested, where these may already have been landfilled in the time taken to evaluate the earlier load. Such situations cased the current regime to be described as unworkable.

Absorbing the LOI testing regime into pre-acceptance checks could provide a solution and would align with other established methods of classification. For example, to determine hazardous status of a waste, the material is tested at least twice a month against sixteen (hazardous) properties before it can be moved, disposed of, or recovered (Environmental Agency EA, 2015). Determined on a 24-sample rolling basis, the material is deemed hazardous if more than five properties exceed the relevant limit or if one property limit is exceeded four times or more (Environmental Agency EA, 2015). Employing routine testing where classification is determined on a rolling-basis would provide a greater level of certainty regarding fines classification prior to disposal, with the responsibility of correct classification squarely placed with the producers. Furthermore, it could be argued that this would better represent the fines being produced over time and be more consistent in classification.

4.8. The LOI test regime is currently not fit for purpose

Meaningful discussions regarding the operational procedures of the QFO are contingent upon an LOI test regime that is fit for purpose and adequately represents the characteristics of qualifying fines. With regard to the latter point, while the use of LOI as a sole measure of environmental burden was questioned, it is noted that it does reflect a key driver of landfill diversion (GHG emission reduction) and it is the authors view that immediate priority should be given to improving the LOI test regime.

Throughout the survey, respondents repeatedly emphasised that the LOI test is severely limited, being both inaccurate and imprecise. The validity of a standardised test is dependent on the reproducibility of results, both within and between laboratories (Geurts et al., 2016). While LOI is often used in soil analysis due to its simplicity and cost-effectiveness, it is generally considered to provide only a crude indication of organic content where test accuracy is known to be affected not only by the sample clay content, but also by a range of procedural details (Hoogsteen et al., 2015; Wang et al., 2011). In addition to the inherent limitations of the test and the failure of the QFO to specify key procedural parameters (thereby leaving it open to interpretation by different test providers), the method and frequency with which samples are obtained has also been criticized for being open to bias and failing to represent the material being landfilled. These limitations could be mitigated by developing a stringent test regime, with little or no room for interpretation, accrediting test providers, and employing third party independent sampling.

5. Conclusions

For waste policy to be effective, particularly in the context of driving the transition to a CE, it should be balanced; providing the correct amount of sanction and incentive to enhance resource recovery while ensuring innovation and investment in progressive waste management strategies is not stifled. Employing a stakeholder-oriented approach, this study has illustrated an example of un-balanced policy, where secondary legislation (the QFO) introduced to address a specific issue (fines classification) has had an unintended negative impact on the principal aim of the primary legislation (the UK LFT) to increase landfill diversion. Specifically, we find that the QFO has created a perverse incentive to decrease landfill diversion through limiting the recovery of secondary materials (underpinning principle of CE) and discouraging investment in technology (required for transition to CE).

While this study found a number of stakeholder dissatisfiers had undermined implementation of the QFO, most notably the complexity of (and missing details in) the QFO guidance and a perceived lack of support from (an unknowledgeable) HMRC, the most critical factors identified were related to policy design. Here, the process for determining the classification of fines and the discontinuity in disposal costs were both identified as major weaknesses with negative impacts on environmental protection, profitability, and investment in technology. These findings highlight both the importance of policy coordination when multiple constraints are present, and the insights that stakeholders can provide (while acknowledging that these will inevitably reflect vested interests) regarding the design and implementation of market-based policy instruments.

With respect to the classification of fines, the current process was found to be open to interpretation and abuse (leading to variation in and misclassification of fines), and was viewed as unworkable and unfair. This arose from a division of responsibility between the producer and the landfill operator, an apparent lack of compliance checks, the time lapse between load delivery and receipt of LOI test results, and a poorly described LOI test regime that is open to sampling bias, lacks methodological details and fails to take account of the inherent limitations of LOI testing. With respect to the discontinuity in disposal costs, the sharp boundary in tax rates at the 10% LOI threshold was not only found to be a blunt instrument for promoting landfill diversion, but one which actively dis-incentivises material recovery leading to a cessation in current separation practices and acting as a barrier to investment in new separation technologies.

To address these issues, the following recommendations are made. First, priority must be given to the development of a robust LOI test method with fully defined operational parameters. This should include an assessment of reproducibility within and between testing laboratories in order to determine an appropriate measurement tolerance that can be taken into account when classifying fines for tax purposes. Second, it is recommended that the balance of responsibility for fines classification is shifted to the waste processor, with LOI determined on a rolling basis and incorporated into pre-acceptance checks (similar to hazardous waste classification). Sampling frequency should be based on risk categories that reflect the composition of input wastes, the processes employed, and the consistency of LOI test results, with third-party sampling and/or regular compliance checks to protect the system from abuse. Third, the 10% LOI threshold should be replaced by multiple tax bands or a sliding scale and ideally would be combined with a direct incentive for investment such as an enhanced capital allowance for resource efficient technologies. At a minimum, it is imperative that the current strong disincentive for recovering inert material is redressed.

As a final note, it is emphasised that explicit consideration must be given to the interaction between environment and technology during the policy design process in order to ensure that the continued evolution of waste management policy is effective.

Declaration of interest

None.

Acknowledgements

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Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:https://doi.org/10.1016/j.resconrec.2018.07.011.

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Appendix 4: Expert Opinion Survey

Industry attitudes towards the Loss on Ignition (LOI) test regime introduced by the Landfill Tax (Qualifying Fines) Order 2015 Survey Instrument

Note: The survey instrument was part of a larger study investigating the introduction of secondary legislation, namely the Landfill Tax (Qualifying Fines) Order 2015 and its impact on primary legislation, namely the Landfill Tax. Only those questions relating to the focus of this paper (respondent profile, impact on resource requirements, and views concerning current and potential improvements to the 10% LOI limit, frequency of testing method and support provided) are reproduced here.

It is also noted that in this survey 22 respondents provided at least one "Don't know" or "N/A" response to a closed question. In the results presented in the paper, all "Don't Know" responses and the majority of "N/A" responses were excluded from the calculation of weighted averages and statistical tests, when considered to reflect either a genuine lack of knowledge on the subject and/or cases where the topic did not apply to the respondent. However, "N/A" responses were retained when respondents were asked about the impact of the LOI testing regime on resource requirements in the workplace. In this instance, the "N/A" response was considered equivalent to, and counted as, a neutral (neither increased nor decreased) response.

Qualification Question

Is your work related to or impacted by the LOI testing regime introduced by the Landfill Tax (Qualifying Fines) Order 2015? *[Multiple Choice (only one answer)]*

○ Yes *[skip to Respondent Profile]*   ○ No *[End of Survey]*

Respondent Profile

Which of the following best describes the organisation you work for? *[Multiple Choice (only one answer)]*

○ Central Government ○ Local Government ○ Non-Governmental/ Non-profit Organisation
○ Academic ○ Consultancy ○ Private Waste Management Company
○ Independent Research Organisation ○ Other (please specify)

Which of the following best describes how your role and/or place of work is related to or is impacted by the LOI testing regime? *[Multiple Choice (only one answer)]*

○ Producer of qualifying material ○ Landfill Operator ○ Research
○ Laboratory/Test provider ○ Policy maker/development ○ Compliance
○ Policy Implementation ○ Other (please specify)

What is your job title? (OPTIONAL) *[Text Box (50 Characters)]*

Briefly outline the main responsibilities of your role (OPTIONAL) *[Text Box (200 Characters)]*

Impact on Resource Requirements

To what extent has the introduction of the LOI testing regime affected your role and/or place of work in the following aspects?(if not applicable to your role and/or workplace please select N/A) *[Multiple choice (only one answer per aspect)]*

	Large increase	Small increase	Neither increased nor decreased	Small decrease	Large decrease	Don't Know	N/A
Operational cost	○	○	○	○	○	○	○
Staff numbers	○	○	○	○	○	○	○
Time allocation	○	○	○	○	○	○	○
Paper work	○	○	○	○	○	○	○
Capital expediture	○	○	○	○	○	○	○
Other (please specify) [Text Box (200 characters)]							

If you have any further comments relating to the introduction of the LOI testing regime, and how it has impacted on your place of work (e.g. influences on business priorities, incentive to separate materials, etc.) please use the space provided below. (OPTIONAL) *[Text Box (200 Characters)]*

Views concerning 10% LOI limit

To qualify for the low rate of tax, fines must be shown to be non-hazardous, have a low greenhouse gas potential and a low pollution potential. To what extent do you think that the 10% limit, imposed by the LOI testing regime, represents these characteristics? *[Multiple choice (only one answer)]*

- ○ I think that the limit is appropriate and represents these characteristics
- ○ I think that the limit is inappropriate as it is too high
- ○ I think that the limit is inappropriate as it is too low
- ○ I think that the limit is inappropriate for other reasons (please specify) *[Text Box (50 characters)]*
- ○ Don't Know
- ○ N/A

If the 10% limit imposed by the LOI testing regime were to be modified to better represent the characteristics required for the lower rate of tax, to what extent do you agree with the following statements? (if not applicable to your job role and/or workplace please select N/A) *[Multiple choice (Only one answer per statement)]*

	Strongly agree	Agree	Neutral	Disagree	Strongly disagree	Don't Know	N/A
The limit is too lax and should be reduced (e.g. 8%)	○	○	○	○	○	○	○
The limit is too strict and should be increased (e.g. 12%)	○	○	○	○	○	○	○
Rather than a specific threshold an extra band should be introduced (e.g. <10%, 10-12%, >12%)	○	○	○	○	○	○	○
Rather than a specific threshold, multiple bands should be introduced (e.g. <8%, 8-10%, 10-12%, 12-14%, >14%)	○	○	○	○	○	○	○

If you would like to briefly explain or elaborate on your response, please do so in the box below (OPTIONAL). *[Text Box (200 Characters)]*

Views concerning testing frequency

After an initial LOI test, frequency of subsequent tests depend on individual circumstances such as pre-acceptance checks, inspection results, previous LOI results and consistency of the previous twenty LOI test results. Informed by these circumstances, three risk categories are used to determine testing frequency (low risk - a sample is tested every 100 tonnes or every six months which ever is first, medium risk - a sample is tested every 500 tonnes or every 3 months which ever is first, and high risk - a sample is tested every load).

To what extent do you agree with the following statements? (if not applicable to your job role and/or place of work please select N/A) *[Multiple Choice (only one answer per statement)*

	Strongly agree	Agree	Neutral	Disagree	Strongly disagree	Don't Know	N/A
The test regime is very clear and I find the testing frequency easy to determine	○	○	○	○	○	○	○
The risk categories used to determine testing frequency are fair	○	○	○	○	○	○	○

If you have any further comments relating to the prescribed testing frequency and/or risk categories please use the space below (OPTIONAL). *[Text Box (200 characters)]*

If the prescribed testing frequency described by the LOI testing regime were to be modified, to what extent to you agree with the following statements? (if not applicable to your job role and/or workplace please select N/A) *[Multiple choice (only one answer per statement)]*

	Strongly agree	Agree	Neutral	Disagree	Strongly disagree	Don't Know	N/A
Rather than using the risk categories set out by the prescribed test frequency to determine number of tests per year, a set number of tests should be fixed for all.	○	○	○	○	○	○	○
The use of risk categories should continue to be used to determine the number of tests per year, but an allowance should be made for spike results.	○	○	○	○	○	○	○
The use of risk categories should continue to be used to determine number of tests per year, but the number of risk categories should be reduced to two.	○	○	○	○	○	○	○
The use of risk categories should continue to determine number of tests per year, but the number of risk categories should be increased to more than three	○	○	○	○	○	○	○

If you would like to briefly explain or elaborate on your response, please do so in the box below (OPTIONAL) *[Text Box (200 characters)]*

Views on support provided to implement the LOI testing regime

Considering the role of HMRC regarding the LOI testing regime, to what extent do you agree with the following statement? (if not applicable to your job role and/or workplace please select N/A) *[Multiple Choice (only one answer)]*

HMRC provides adequate support for the implementation of the LOI testing regime.

○ Strongly agree ○ Agree ○ Neutral ○ Disagree

○ Strongly disagree ○ Don't Know ○ N/A

If you have further comments relating to the role of the HMRC regarding the LOI testing regime please use the space below (OPTIONAL). *[Text Box (200 characters)]*

If the role of HMRC regarding the LOI testing regime were to be modified, to what extent do you agree with the following statements? (if not applicable to your job role and/or workplace please select N/A). *[Multiple Choice (only one answer per statement)]*

	Strongly agree	Agree	Neutral	Disagree	Strongly disagree	Don't Know	N/A
Guidance should be simplified	○	○	○	○	○	○	○
More support should be made available to interpret the LOI testing regime	○	○	○	○	○	○	○
HMRC should endorse specific processes and/or machinery for the production of qualifying fines	○	○	○	○	○	○	○
HMRC should introduce tax breaks for technology investment	○	○	○	○	○	○	○
Laboratories used for LOI testing should be standardised/ accredited	○	○	○	○	○	○	○
Sampling of fines should be undertaken by an independent third party that are accredited	○	○	○	○	○	○	○

If you would like to briefly explain or elaborate on your response, please do so in the box below (OPTIONAL). *[Text box (200 characters)]*

If you have any further comments, or ideas, relating to the improvement of the LOI testing regime, please use the space below (OPTIONAL). *[Text Box (200 characters)]*

[End of Survey]

Appendix 5: Example ethics documents

With regards to participation in the expert opinion survey, consent was implied with completion of the survey. Below is a copy of the first page of the survey.

Industry attitudes towards the Loss on Ignition (LOI) test regime introduced by the Landfill Tax (Qualifying Fines) Order 2015

Welcome

Thank you for taking the time to participate in this short survey concerning attitudes towards the Loss on Ignition (LOI) testing regime introduced by the Landfill Tax (Qualifying Fines) Order 2015.

The survey includes 20 questions and is divided into 4 sections as follows:

(1) About you and your workplace.
(2) How the introduction of the LOI testing regime has impacted your place of work.
(3) Your opinions on specific parts of the LOI testing regime.
(4) Your opinions on potential points of improvement.

Mandatory questions are marked by an asterisk (*).

The survey should take approximately 5-10 minutes to complete (depending on how many comments you wish to add, and whether or not you answer the optional questions).

The survey does not ask you to disclose any personal information. Any information you do provide will be fully anonymised, and the data collected will only be used for research purposes.

At the end of the survey, there will be an option for you to enter a prize draw for a chance to win an iPad mini.

All complete responses are eligible to enter the draw.The draw will take place onMonday 11th July 2016 and the winner notified by email. If you do not wish to enter, there is no need for you to provide an email address

If you would like any further information, please do not hesitate to contact me at:

carly.fletcher@stu.mmu.ac.uk

or my supervisor, Dr Rachel Dunk:

r.dunk@mmu.ac.uk

Thank you in advance

Carly Fletcher

PhD Student
School of Science and the Environment
The Manchester Metropolitan University

Concerning the workshop, consent was implied through participation, and in accordance with GDPR, participants had to opt-in to consent to any follow-on communication.

Symposium of Urban Mining, Bergamo, May 2018
NeWs: "Circular Economy Readiness (CER)"
Co-ordinated by: Dr. Rachel Dunk & Carly Fletcher

Manchester Metropolitan University

Waste2 Resource Innovation Network

Please fill in the table below and introduce yourself to the group.

Group Number:

Name	Email	Country	Role	Area of expertise	*Opt-In?

*We would like to circulate the outcomes of this workshop (along with suggestions, if any, for future research) to all participants. **Please opt-in if you agree to be sent information pertaining to this workshop.** Contact information will be used for this purpose only, and all data collected will be anonymised with any personal information stored securely (on a password-protected computer or in the case of hard copies, in a locked cabinet). This will be retained for the duration of the research (up to 3years).

Activity 1: Contribution of waste and resource management to the circular economy.

(a) **Discuss how waste and resource management contributes to the circular economy?**

Things to think about;

- *What is the overall function of waste and resource management, have the priorities changed?*
- *Do current waste and resource management strategies / activities preserve or destroy resources?*
- *How easy is it to identify and locate preserved resources?*
- *How easy is it to reclaim and recirculate preserved resources, now and in the future?*
- *Should landfill diversion and the application of the waste hierarchy remain major drivers of waste strategy? If not, what could replace them?*
- *How flexible are the facilities and technologies of today, could they incorporate or integrate with newer, more effective, technology in the future?*

(b) As a group, how do you think waste and resource management can contribute to the circular economy, both now and in the future?

Now

⇒

⇒

⇒

Future

⇒

⇒

⇒

Appendix 6: Raw data – counts for document analysis

	England WMS	England WPP	Scotland	Wales WMS	Wales WPP	NI
AIMS						
sustainable development	0	0	1	24	11	19
ECONOMY / ECONOMIC PROSPERITY	17	27	36	67	20	22
low carbon	0	0	1	0	5	1
Circular economy	0	13	0	0	1	2
move away from Linear economy	0	1	1	0	0	0
sustainable economy	3	8	3	7	0	0
green economy	0	0	2	0	0	7
strong and enterprising' economy	0	0	0	1	0	0
zero waste economy	5	0	23	19	0	0
economic growth total	9	1	3	0	9	6
green jobs / employment	0	4	3	40	5	6
ENVIRONMENTAL PROTECTION	50	12	76	119	8	145
environmental protection	40	0	43	64	1	94
Climate change & ghg emissions	**10**	12	**33**	**55**	7	**51**
Climate change / global warming / GHE	**2**	0	**15**	**19**	2	**20**
climate change	2	0	15	17	2	19
global warming / GHE	0	0	0	2	0	1
GHG / carbon emissions	**8**	12	**18**	**36**	2	**31**
greenhouse gas emissions	2	3	12	31	1	15
reduce carbon/climate impact	3	1	4	0	1	13
carbon emissons / carbon intensive	2	2	2	2	0	1
CO2/CO2e emissions	1	6	0	3	0	2
Non ghg / general refs to pollution	**5**	0	**5**	**9**	3	**3**
Pollution / Pollutant	3	0	4	7	1	2
non-ghg/carbon emissions/discharges	2	0	1	2	2	1
SOCIAL / SOCIAL EQUITY	10	10	7	71	13	23
human/public health	10	3	5	16	8	13
social benefits	0	7	2	14	0	2
social well-being	0	0	0	12	1	4
quality of life	0	0	0	5	1	4
social justice / fair and just society	0	0	0	16	2	0
equality (of opportunity)	0	0	0	8	1	0
FUTURE GENERATIONS		6			13	
cultural legacy	0	0	0	6	0	0
general ref to shaping the future / decisions/goals investment etc	1	4	8	0	5	7
sustainable future	0	0	0	4	2	0
healthy future	0	0	0	4	0	0
future generations	0	0	1	3	2	4
future WM needs / future waste streams/types (legacy wastes)	10	2	4	4	4	1
CORE CONCEPTS & PRINCIPLES						
RESOURCE EFFICIENCY						
RESOURCES	**24**	**21**	**74**	**75**	**15**	**88**
OF WHICH						

general comment on resource use	0	14	17	4	12	5
resource management	3	7	9	6	3	6
resource efficency	**21**	**34**	**48**	**65**	**26**	**77**
resource efficiency as justification for landfilling some wastes	2	0	0	0	0	0
resource efficiency (as term)	5	34	4	20	26	51
resource efficiency (in context - valuing resources fewer resources etc...)	**14**	41	**44**	**45**	29	**26**
OF WHICH waste as a resource	*2*	1	*5*	*7*	6	*5*
AND valuing resources	*4*	8	*19*	*16*	6	*4*
AND replace virgin	*1*	0	*4*	*2*	1	*0*
AND using fewer / reduce etc	*3*	6	*7*	*16*	4	*10*
AND general ref to efficiency / efficient use of resources	*4*	26	*9*	*4*	12	*7*
LIFE CYCLE THINKING						
Life cycle TOTAL	**4**	6	**12**	**26**	18	**29**
lifecycle / lifecycle thinking (inlcude life cycle, life-cycle, lifecycle)	1	6	1	9	14	15
reference to life stages	2	0	4	3	3	10
cradle to cradle	0	0	0	1	0	0
closed loop	1	0	7	13	1	4
down cycling	*0*	0	*1*	*0*	0	*0*
open loop recycling	*0*	0	*0*	*8*	0	*1*
SUSTAINABLE PRODUCTION AND CONSUMPTION						
SPC/SCP	0	0	0	9	4	4
LIMITS TO GROWTH / DECOUPLING						
Decoupling economic growth	1	1	0	0	14	4
environmental limits / limits to growth	0	0	0	16	4	0
fair share	0	0	0	4	0	0
CHANGE & AVOIDING LOCK-IN						
change	4	34	14	25	29	6
transformational change	0	0	1	0	0	2
future proofing / resilient re future needs/demands / ability to upgrade	0	3	0	3	11	0
current legacy wastes (not incl. in future)	0	0	0	6	2	0
avoid lock in	0	0	0	0	0	0
ENABLERS						
TECH INNOVATION & INVESTMENT						
TECHNOLOGY						
Technological progress (tech)	11	6	9	10	5	13
Innovation TOTAL	3	10	4	1	25	4
innovation (in sectors other than waste/resource)	2	3	1	0	17	2
INVESTMENT		14			16	
Infrastructure	25	1	33	24	11	21
installations	10	0	8	16	0	7
investment	6	13	15	1	5	5
BUSINESS MODELS						
business models	1	12	0	0	10	0
supply chains (and supply system)	5	17	1	13	23	11

CONSUMERS AS ENABLERS						
behaviour	3	4	5	11	14	6
acceptance / acceptability (public / social) of changes	0	0	0	5	0	3
attitudes	1	0	2	0	1	1
views	0	0	1	0	3	0
SECONDARY MARKETS						
market for recyclate / market development	6	2	11	25	15	15
TYPES OF MEASURES & INSTRUMENTS						
TARGETS & METRICS						
targets	26	6	55	85	49	59
carbon footprint	0	3	0	1	1	2
carbon metric	0	0	12	0	2	0
ecological footprint	0	0	0	65	3	0
FINANCIAL						
tax	4	1	0	1	1	9
incentives	4	1	2	3	1	6
green procurement	1	10	2	12	37	7
PRODUCER RESPONSIBILITY						
SUM producer respon/polluter pays	**12**	5	**2**	**12**	4	**19**
Producer Responsibility	8	5	2	8	4	14
Polluter Pays	4	0	0	4	0	5
VOLUNTARY AGREEMENTS						
voluntary agreements / standards	3	10	3	4	9	15
PUBLIC ENGAGEMENT						
SUM public engagement						
education	0	5	10	1	5	11
communication	0	7	0	6	12	13
awareness campaign/programme	0	7	9	2	15	5
engagement	*1*	7	*6*	*3*	13	*3*
ref to increasing awareness	*0*	0	*0*	*0*	0	*0*

Appendix 7: Stakeholder Responsibilities – England

Stakeholder responsibilities within the waste management strategy (WMS) and waste prevention plan (WPP) documents for England. (WMS) and (WPP) indicate where responsibilities are included in only one document

Stakeholder	Responsibilities
International	Set overarching legislation and objectives. Introduce broad programmes to assist with meeting objectives. Require the collection of data to assess progress (WMS).
National	Transpose international legislation into national objectives. Set targets, provide support and guidance. Encourage sustainable thinking within resource and waste management. Produce quality standards for recycled materials (WMS). Identify suitable locations for future facilities (WMS). Monitor and review progress. Provide information and data to other stakeholders, support collaborative action. Drive behaviour change. Support development of thriving and innovative industries to enable change (WPP). Boost economic growth whilst continuing to improve the environment (WPP). Lead by example e.g. green procurement (WPP).
Government Departments & Non-Gov. Public Bodies	Implement international and national legislation and policy. Provide funding for schemes / investment opportunities. Organise voluntary sector agreements. Distribute environmental permits (WMS). Conduct routine inspections (WMS). Provide advice and guidance on the of waste hierarchy strategies and support inter-stakeholder collaboration. Provide data and evidence regarding current and future waste management activities. Initiate and/or respond to consultations (WMS). Implement plans / carry out trials / develop tools to catalyse cross-sector and community action (WPP).
Regional	Obligated to implement national legislation, provide waste collection services, and support businesses in meeting their responsibilities. Work in partnership with the waste sector to ensure full and efficient waste services. Record and report waste data and illegal activity. Provide evidence to consultations (WMS). Promote action within the local area (WPP).
Waste Sector	Adhere to national and international legislation and relevant environmental permit conditions (WMS). Where appropriate, develop actions to meet quality standards and change behaviours to contribute to national objectives. Obligated to provide waste collection services that are regular, efficient and affordable (WMS), working in partnership with local authorities and other regional stakeholders. Contribute to future waste strategy by providing evidence regarding current activities and responding to consultations (WMS).
Other Business & Industry	Adhere to national and international legislation, meet sector specific targets, participate in voluntary agreements, and provide private financial initiatives. Supported in recognising and capitalising on resource efficiency opportunities and encouraged to incorporate sustainable thinking into product/service design. Implement service systems / develop service models that make waste prevention, reuse and repair easier and improve confidence in second-hand goods (WPP). Contribute to future waste strategy by providing evidence regarding current activities and responding to consultations (WMS). Look at own practices to identify opportunities (WPP).
Consumers	Provide evidence on current waste management activities and can respond to consultations (WMS). It is acknowledged that consumers are the main contributors to waste generation and that a change in behaviour would contribute to national objectives; however, they are not held responsible or accountable by any policy mechanism.

Appendix 8: Stakeholder Responsibilities – Scotland

Stakeholder responsibilities within the combined WMS /WPP document for Scotland.

Stakeholder	Responsibilities
International	**Set overarching legislation and objectives. Introduce broad programmes to assist with meeting objectives. Promote the waste hierarchy and high-quality recycling. Require the collection of data to assess progress.**
National	Introduce policies, targets and strategies to address the requirements of international legislation. Develop programmes, promote the waste hierarchy and best available techniques, introduce measures that value resources, and develop secondary materials markets. Provide guidance, tools and support to encourage good practice, and promote long-term stability, eco-design and investment. Stimulate behaviour change by strengthening market confidence, developing measures to influence behaviour, and providing reliable information. Information is collected and reviewed to measure progress with respect to targets and the success of implemented measures and initiatives.
Government Departments & Non-Gov. Public Bodies	**Enforce regulatory frameworks and provide other regulatory functions to control relevant activities, develop programmes and tools, and provide guidance for the delivery of zero waste plans and policies. Enable efficient resource use. Encourage investment in innovative technologies. Contribute to the design of non-waste facilities / activities. Provide evidence to consultations and macro level studies.**
Regional	Adhere to regulatory frameworks. Develop programmes and strategic waste infrastructure plans with neighbouring regions. Provide leadership in areas of influence and to achieve value for money with respect to procurement. Provide evidence for consultations, adhere to audits, report data, and contribute to relevant planning applications.
Waste Sector	**Adheres to regulatory frameworks. Partial responsibility for compliance. Responsibility regarding investment in capacity and infrastructure considering national policy. Develop good practice commitments. Adhere to audits, and report information concerning compositional data, services provided, and voluntary opportunities. Increase workplace skills. Public engagement.**
Other Business & Industry	Adhere to regulatory frameworks. Responsibility for investment in capacity and infrastructure considering national policy. Subject to sector-specific programmes. Adhere to good practice commitments. Develop innovative technologies. Responsibility for reducing waste generated under their control through resource efficiency opportunities and the incorporation of sustainable thinking into product/service design. Provide evidence to consultations. Participate in awareness campaigns. Improve understanding and usage of resources.
Consumers	**Active participation in programmes and initiatives. Provide evidence to consultations. Involvement in waste infrastructure planning process. Increase understanding of consumption and waste generation. Recognise and take responsibility for the waste generated. Implored to be enthusiastic and take action.**

Appendix 9: Stakeholder Responsibilities – Wales

Stakeholder responsibilities within the waste management strategy (WMS) and waste prevention plan (WPP) documents for Wales. (WMS) and (WPP) indicate where responsibilities are included in only one document.

Stakeholder	Responsibilities
International	**Set overarching legislation and objectives. Introduce broad programmes to assist with meeting objectives.**
National	Transpose international legislation and objectives. Provide a long-term vision to reduce Wales' ecological footprint to within environmental limits (WMS). Apply key principles (precautionary principle, polluter pays principle, proximity principle, waste hierarchy, and equality of opportunity) (WMS). Set domestic targets and sector-specific objectives. Introduce penalties for non-compliance (WMS). Grant powers to regulators for enforcement (WMS). Explore initiatives. Develop sector plans (including voluntary targets). Raise awareness. Provide advice and support regarding secondary materials markets, IPP, and waste infrastructure. Promote broader themes of zero-waste, sustainable development and citizen empowerment. Collect and publish data. Monitor indicators of progress (ecological footprint of waste, provision of recycling services, destination of recyclates, outcomes of eco-design programmes, wellbeing, employment, and skills). Implement 4E model of behaviour change (WPP). Identification and engagement with key sectors and industries (WPP).
Government Departments & Non-Gov. Public Bodies	**Ensure and enforce compliance (WMS). Develop and implement campaigns (WMS). Support local capacity/infrastructure plans and skills development. Provide information on technical requirements (WMS). Assess skills gaps (WMS). Consult on legislation. Encouraged to adopt sustainable waste management practises and drive change through procurement and exemplarily behaviours. Identification and engagement with key sectors and industries (WPP).**
Regional	Provide waste collection services and implement engagement campaigns (WMS). Support alternatives to landfill and encourage systems that treat waste as a resource to ensure greater consistency in recycled materials. Collect and report data to evaluate progress towards waste prevention goals, best practice, and value for money.
Waste Sector	**Adhere to legislation (WMS). Implement waste strategy (WMS). Provide waste collection services (WMS). Introduce programmes/initiatives that promote closed loop recycling. Assess infrastructure requirements (WMS). Establish integrated networks of waste facilities (WMS). Address skills gaps and increase the number of green jobs.**
Other Business & Industry	Implement waste strategy (WMS). Adhere to sector specific plans (and achieve sector-specific targets). Develop and implement voluntary arrangements that consider the polluter pays principle, extended producer responsibility and IPP. Exert influence through procurement activity. Employ eco-design / eco-innovation to reduce product impacts (including use of recycled/alternative materials and avoiding the generation of legacy wastes). Contribute to feedback mechanism by recording and submitting data. Assessing skills gaps within their own sector. Share responsibility for waste generated and future proof against future resource competition. Develop sustainable products and services, invest in high quality jobs and implement alternative business models (WPP).
Consumers	**Encouraged to develop local exchange schemes and participate in national educational and engagement schemes (WMS). Workers are encouraged to recognise and rethink their influence within the workplace and at home regarding procurement and consumption. Contribute to the well-being of Wales, resource efficiency and waste reduction.**

Appendix 10: Stakeholder Responsibilities – Northern Ireland

Stakeholder responsibilities within the combined WMS / WPP document for Northern Ireland.

Stakeholder	Responsibilities
International	**Set overarching legislation and objectives. Introduce broad programmes to assist with meeting objectives. Provide access to officials to support implementation of programmes and objectives. Identify financial and non-financial opportunities.**
National	Ensure compliance with international policy. Develop (all-island) compatible and complementary policy. Participate in international and UK initiatives. Propose sector-specific targets. Develop domestic re-use and voluntary quality assurance schemes. Reduce burdens on business and support resource efficiency. Collect and publish information on waste flows, commodity prices, and legislative proposals.
Government Departments & Non-Gov. Public Bodies	**Develop, monitor and enforce waste management strategy and accompanying policies and regulations. Use a suite of penalties and sanctions to ensure compliance. Grant funds for schemes and initiatives. Develop programmes and educational campaigns. Explore and exploit economies of scales. Support market development. Promote collaboration. Provide information. Instrumental in consulting on strategies, legislation and spatial aspects.**
Regional	Adhere to national and international legislation. Use powers to improve the quality of the environment. Responsible for planning aspects of waste management strategies. Work in partnership with regulators, other regional stakeholders and the third sector to tackle poor compliance, develop schemes and initiatives, and provide advice. Collect and report data. Provide evidence to consultations and participate in studies, campaigns and inspections.
Waste Sector	**Adhere to national and international legislation and permit/ licence conditions. Deliver domestic targets and actions. Develop and utilise programmes and investment schemes to introduce innovative waste collection schemes and integrate facilities on an all-island basis. Implement codes of practice. Support local authorities and communities to adhere to the waste hierarchy. Contribute to consultations. Collect and report data regarding specific waste streams.**
Other Business & Industry	Adhere to national and international legislation, and sector specific domestic targets. Develop and participate in voluntary initiatives. Build market confidence. Consider best available techniques.
Consumers	**Participate in campaigns. Promote social enterprise along with green jobs. Instigate improvement through public engagement and social acceptance.**